TABLE OF CONTENTS - HORSE FOSSIL KIT
John Day Fossil Beds National Monument

These Labs are presented in this order on the enclosed CD …

LAB 9 … Optional Activities

Horse Kit Overview & Feedback (a folder on the CD)

UNDER CONSTRUCTION – WILL BE ADDED LATER

JODA – October, 2006

LAB 1: Introduction to the John Day Fossil Beds & Horses Over Time (Teacher Directions)

OVERVIEW: This film activity is intended as an introduction to the John Day Fossil Beds
National Monument. It will help prepare the students for the subsequent lab activities, which are
targeted toward specific 2005 ODOE science curriculum benchmarks. The questions below can be
answered by viewing the films.

TIME LIMITS: Viewing 2 of the films on the DVD, and discussing the questions, should take
about 45 minutes (one class period). You will need a DVD player and a monitor, or screen, large
enough to be viewed by the entire class.

TEACHER PREPARATION: The teacher should view the five minute film on horse evolution in
advance of your classroom discussion, and become familiar with the physical changes in horses
over time, especially in the teeth.

Ø For each student, make a copy of LAB 1 – SHEET 1 and SHEET 2.

Ø (optional) For each student, make a copy of LAB 1 – SHEET 3, to help show that the horse family tree can be looked upon as a branch, part of a tree limb called *perrissodactyla*, that tree limb in turn part of the bigger mammal family tree. You could have one or two copies to hand out later for students to look at, instead of many copies.

CLASSROOM FILM & DISCUSSION: In this class period students will view two films having information that will prove useful in their later lab studies of horse fossils.

Film One … John Day Fossil Beds: A Place of Discovery -18 minutes

Before the film starts have the students think about these questions as they view the film.

a. What sciences are practiced at John Day Fossil Beds National Monument?

(**brief answer:** the science of paleontology, made up primarily of geology and biology [biology = zoology & botany & animal and plant behavior])

b. What does the geology and fossil record at John Day Fossil Beds tell us about the climates and ecosystems of eastern Oregon's past?

(**brief answer:** over the last 50 million years the climate has followed the general pattern of showing increasing seasonality with wider variations in temperatures over a year, a cooling average yearly temperature overall, and less moisture per year. The plant ecosystems have reflected this, starting with near-tropical, hardwood deciduous forests covering the northwest, to the advent of grasses and fewer tropical trees, to tree and grass savannas, to grasslands, to the near-desert plants we have today at the fossil beds.)

c. What animals did you not expect to find living on the North American continent that were found at the John Day Fossil Beds?

Film Two … Equine Evolution - 5 minutes

Before the film starts have the students read LAB 1 – SHEET 1, and then look over SHEET 2 for a couple minutes. You and the students will use SHEET 2 for discussion after the film.
If you are using SHEET 3 hand it out now. Ask the students to keep these two questions in mind as they view the film, then discuss the answers after the film:

d. What physical changes occurred in horses during its history?

(brief answer: over-all size, teeth changes – premolars changing into molar shape, teeth becoming longer, teeth becoming harder with cementum, eye socket moving toward rear of skull, number of toes reducing from four to one on each limb, skull elongating)

e. What type of plant ecosystems did the horse live in over time?

(brief answer: Well the answers are in the film of course, but you should touch on

the following changes in horses over time … length of teeth, premolars becoming molars, complexity of patterns on the tops of teeth, the added substance that helped

teeth resist wear, the eye socket movement in the skull from front to back, the numbers of digits [toes] on each foot over time, the method of escape from predators, and over-all size of the horse. A few horses got larger then smaller over time, but most branches of the family tree got bigger. Only two plant ecosystems were mentioned, a wet jungle-like environment and then later a grassland environment.)

After your discussion of the above questions, ask the students to take out LAB 1 – SHEET 2 along with a pencil. Tell them you are going to read off all the genus names of horses that were mentioned in the film. They are to circle the names on their SHEET 2, horse family tree diagram. Read these names off in this order:

Hyracotherium … Orohippus … Mesohippus …Miohippus … Parahippus … Merychippus … Pliohippus … Equus … Then ask these questions ...

f. Eight genera of horses were named in this film produced by the Smithsonian Institute. In a short six minutes, they tried to give you an idea of the changes in horses over time. In your opinion, did they succeed in showing the diversity of changes in the horse family tree?

g. Based on information present on the SHEET 2 diagram, what did the film fail to mention about horses over time? (i.e. What was left out of the film?)

h. There are many branches on the family tree diagram. What does the end, or tip, of a branch represent, what word would you call it? (answer: extinction)

i. About how long did *Nannippus* live before it became extinct? (answer: 5 my)

STOP … Congratulations! You have just completed Lab 1.

LAB 1 - SHEET 1

Modern Horse Foot

The photo image shows a modern horse foot. On the rear of each foot of every modern horse, wild or tame, are two splint bones.

The splint bones are not visible on a living horse as they are under skin, muscle, and tendon. These bones are sensitive to a horse and fragile, easily broken. They are of no use to a horse.

Why do horses have these two splint bones?

There are four joints (where two bone segments meet) visible on this horse foot. The top of the foot is one joint. See the other three joints?

Starting with *your* wrist joint, count the joints leading to a fingernail on your hand. There are four. From your ankle joint to one of your toenails, there are four joints. Your fingernails and toenails are made of the same material, matted hair. So is a horse hoof, matted hair.

Why are your hand and foot bones so similar to a horse's foot bones?

Early mammals started with five digits on each limb. The horse is the only living mammal that has evolved from an ancestor with five digits on each limb down to a single digit per limb.

If you wanted to run like a horse you would need to select one finger from each hand, and one toe from each foot. Then, pointing your two fingers and two toes straight down, run on the tips of your fingernails and toenails. Ouch!

LAB 1 - SHEET 2

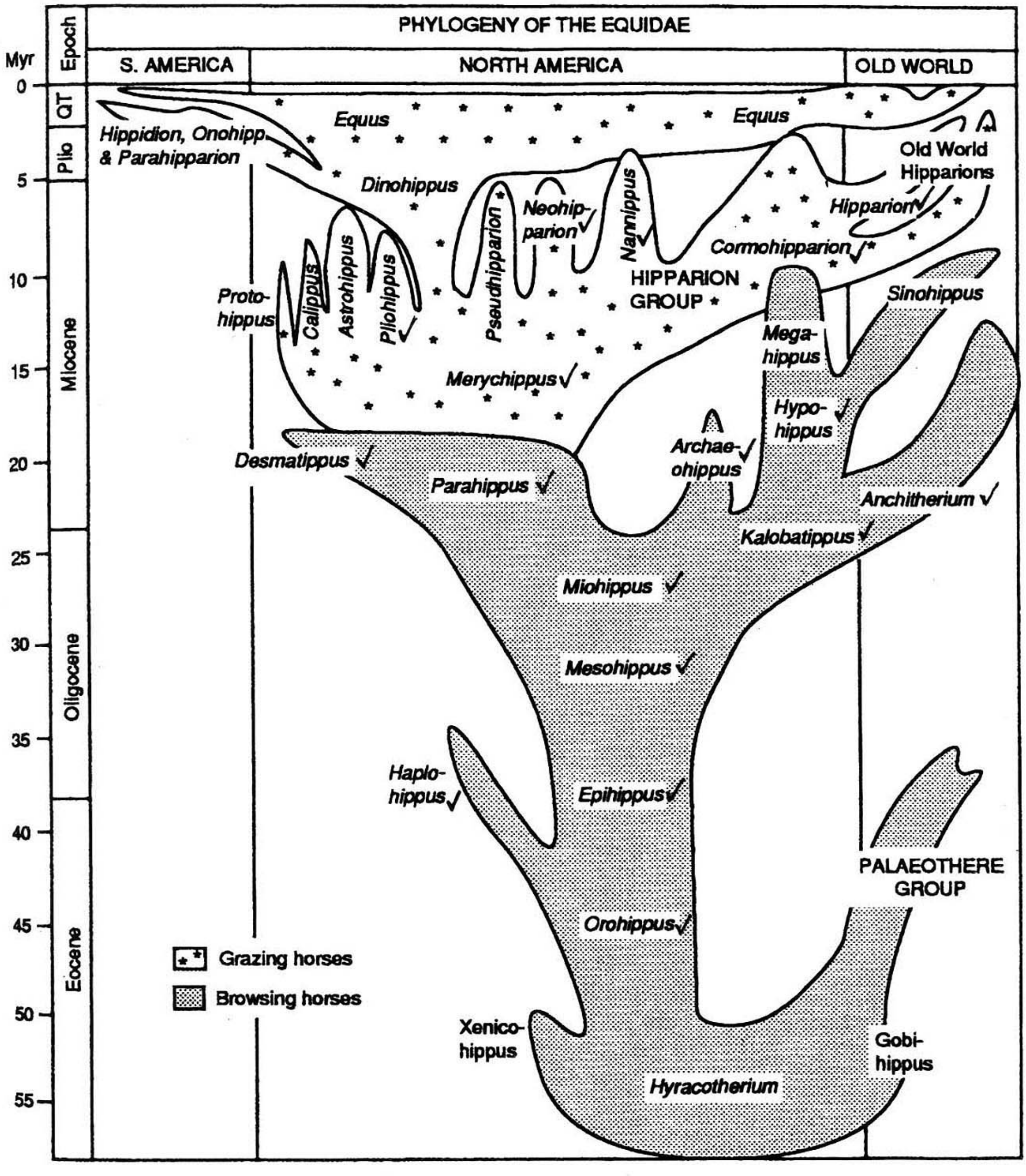
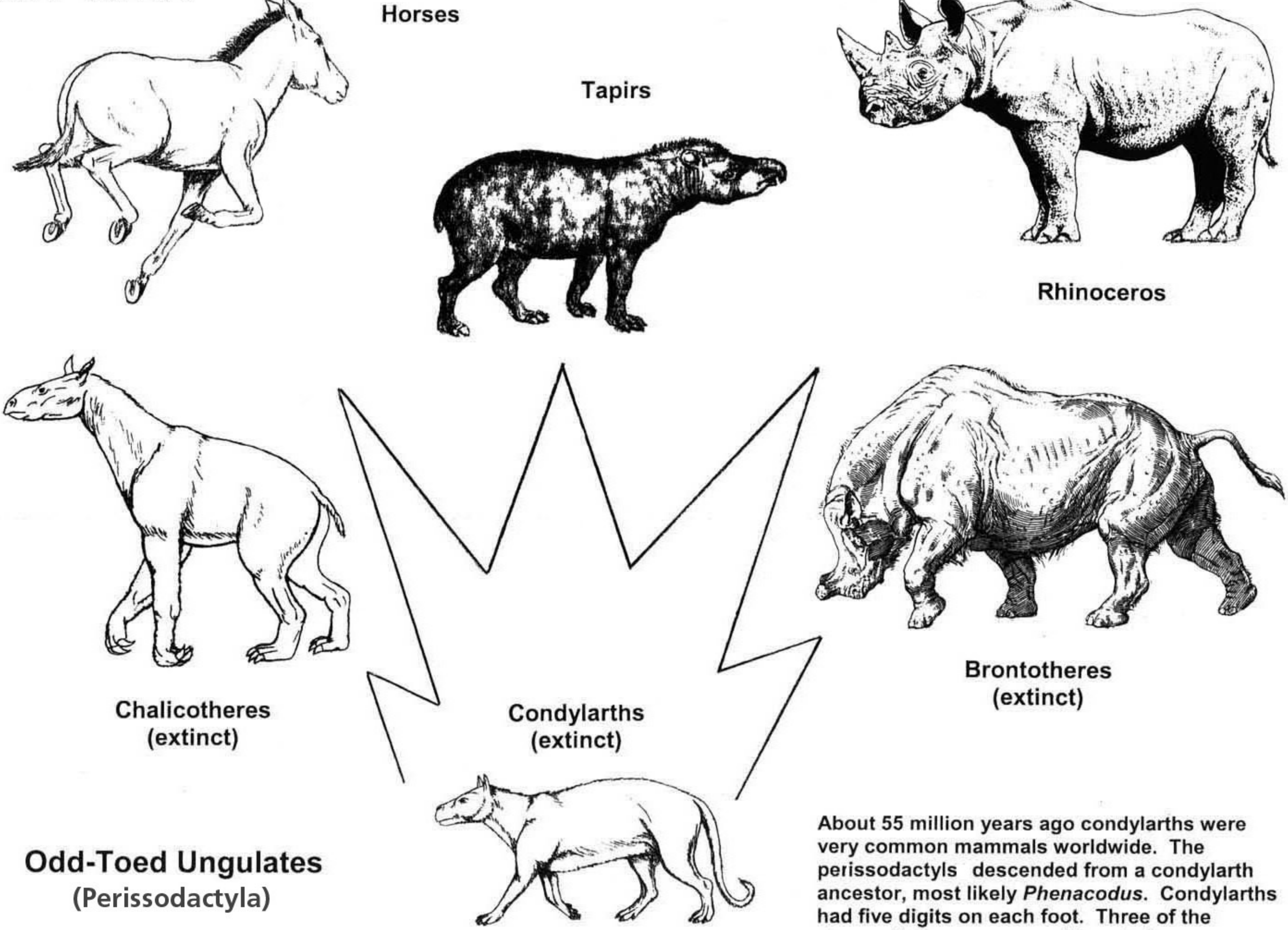


Figure 5.14. *Interrelationships of the currently recognized genera of horses. Note that in the Old World, in addition to the genera* Hipparion *and* Cormohipparion, *the interrelationships of the "Old World Hipparions" are poorly understood and include the endemic* Stylohipparion, Cremohipparion, Sivalhippus *group, and* Proboscidipparion.

The chart above is from the book <u>Fossil Horses</u>, by Bruce J. MacFadden, copied with his permision. Note that check marks have been added and indicate the horse fossil genera found at the John Day Fossil Beds.

LAB 1 - SHEET 3



Odd-Toed Ungulates
(Perissodactyla)

About 55 million years ago condylarths were very common mammals worldwide. The perissodactyls descended from a condylarth ancestor, most likely *Phenacodus*. Condylarths had five digits on each foot. Three of the descending groups are with us today.

John Day Fossil Beds Perissodactyla (Odd-Toed Ungulates) Fossil Finds (listed by genera)

LAB 2: A Study Of Horse Fossils (Teacher Directions)

OVERVIEW: This is the primary study lab in this horse kit. Students will be able to handle sixteen horse fossils, make measurements and observations, draw conclusions to questions presented, and discuss interpretations of the data.

PREREQUISITE: Student completion of Lab 1 (at least seeing and discussing the horse film).

ODOE STANDARDS: This activity targets the following 2005 science standards. It has been designed for easiest use with 8th through 12th grade students in mind. The lab has been adapted by teachers for use with 6th and 7th graders, generally entailing more explanations by the teacher conducting the lab and adding more time for the students to process the information and conduct the activities.

Life Science: Understand structure, functions, and interactions of living organisms and the environment.

> **Common Curriculum Goal**: Diversity/Interdependence – Understand the relationship among living things and between living things and their environment.
>
> > **Benchmark 3 (Grade 8)** – Describe and explain the theory of natural selection as a mechanism for evolution.
> >
> > **CIM/CAM** – Analyze how living things have changed over geological time, using fossils and other scientific evidence.
>
> **Common Curriculum Goal**: Analyzing and Interpreting Results – Analyze scientific information to develop and present conclusions.
>
> **Benchmark 3 (Grade 8)** - Summarize and analyze data including possible sources of error. Explain results and offer reasonable and accurate interpretations and implications.
>
> **CIM/CAM** - Summarize and analyze data, evaluating sources of error or bias. Propose explanations that are supported by data and knowledge of scientific terminology.

TIME LIMITS: This study package is designed to be conducted over the course of two 45 minute class periods. Over these two class periods there are a total of six lab sections. Lab sections range from 20 to 10 minutes in length.

There are about 30 minutes of student research needed before the class lab is conducted, entailing the reading of handouts. The students will use the same handouts during the lab, and should be reminded to bring them to the lab.

TEACHER PREPARATION BEFORE LAB: Before the lab begins, the teacher should prepare the following. This will take some time and should be done before the class periods the lab will be conducted.

- Ø Divide the class into four teams of students (equal numbers if possible), and assign each group a team leader. For each student, make a copy of LAB 2 – SHEET 1 and SHEET 2 (and for the CIM-CAM students SHEET 3). Have the students bring out their previous copy of LAB 1 – SHEET 2.

- Ø The teacher should have a copy of this document with them as it contains the student directions from LAB 2 – SHEET 1, plus the prompts and answers. The teacher will also need a copy of LAB 2 – SHEET 4 TR, for the last part of this lab.

- Ø Have a clock that is readily visible to all. Lab sections are timed.

- Ø Set up four tables, each with plenty of surface area for fossils and paperwork, and enough chairs for students to sit at the tables. Number the tables 1 through 4. Each table should have a ruler that measures metric. Separate the tables from each other as much as possible. There will be one team per table. Teams will be rotating from table to table during the lab.

- Ø Carefully distribute the fossil specimens onto the tables as per the ID list below. They MUST be divided into the following four groups of specimen numbers. Do NOT mix specimens among tables at any time. Please make note of any damaged specimens at this time.

Table #1: FAM 60300, JODA 3363, JODA 4664, UCMP 114475

Table #2: FAM 60800, JODA 1086, UCMP 114476, UCMP 63617

Table #3: AMNH 4832, LACM 1863, UCMP 82485, UCMP 121890

Table #4: FAM 60700, AMNH 8174, UCMP 68499, UCMP 82497

STUDENT RESEARCH BEFORE CLASSROOM LAB: Before the lab is conducted in the classroom, students will need to do some basic background research, all of it reading. Have the students read and become familiar with the following LAB 2 sheets, and have them bring these sheets to the classroom lab:

- Ø LAB 2 – SHEET I (lab directions, procedures, and questions)

- Ø LAB 2 – SHEET 2 (tooth development)

- Ø For the CIM/CAM students, LAB 2 – SHEET 3 (tooth wear)

- Ø Look over the previous LAB 1 – SHEET 2 (horse family tree)

Have the students bring all of the above sheets to the classroom lab.

<u>CLASSROOM LAB WORK STARTS HERE</u>
(six sections over two 45 minute class periods)

Please warn the students to be very careful handling these breakable fossil replicas. Always use two hands when picking up and holding the larger skulls.

LAB 2 - Section One (the students will have 20 minutes for this section):

A. The team leader will read the directions on their LAB 2 – SHEET 1 directions and lead the group efforts. All should jot down answers to questions on their personal copies, but the team leader's copy will have the answers for the group, used for comparision to the other teams' answers.

Each team should work as a team, getting everyone involved. Open discussion in each group is encouraged, sharing observations is needed.

The first couple lab sections will move slow. Then as the students get into the lab routine it will pick up speed. This is good, but rushing to get answers just to finish fast may cause inaccuracies. Have the leaders double check answers and/or get group concensus before moving on.

All teams will start each lab section at the same time, so should they finish early, do not let them move on to the next section until all teams are ready to move on.

B. Each team will look over the four fossil specimens on their table, checking to be sure they have the right four specimens. Should the students wish to know where the an original fossil specimen is kept:

FAM stands for "Frick collection, American Museum of Natural History," New York City.
AMNH stands for "American Museum of Natural History" collection.
JODA stands for "John Day Fossil Beds National Monument" collection.
UCMP stands for "University of California Museum of Paleontology" collection.
LACM stands for "Los Angelos County Museum" collection.

C. What follows are the directions the students have in their hands to follow as they conduct the six lab sections.

Teacher prompts and some answers will be presented throughout, most of the answers are presented at the end.

Keep an eye on the time for the students, and give them warnings regarding how much time is left.

ESTIMATING HORSE SIZE: The body length of a horse may be used to estimate the general size or mass of the horse. In this lab activity we do not have the fossil bodies of horses, but you will be able to estimate the body length (BL) of a horse fossil by measuring another part of the fossilized body, the length of the skull.

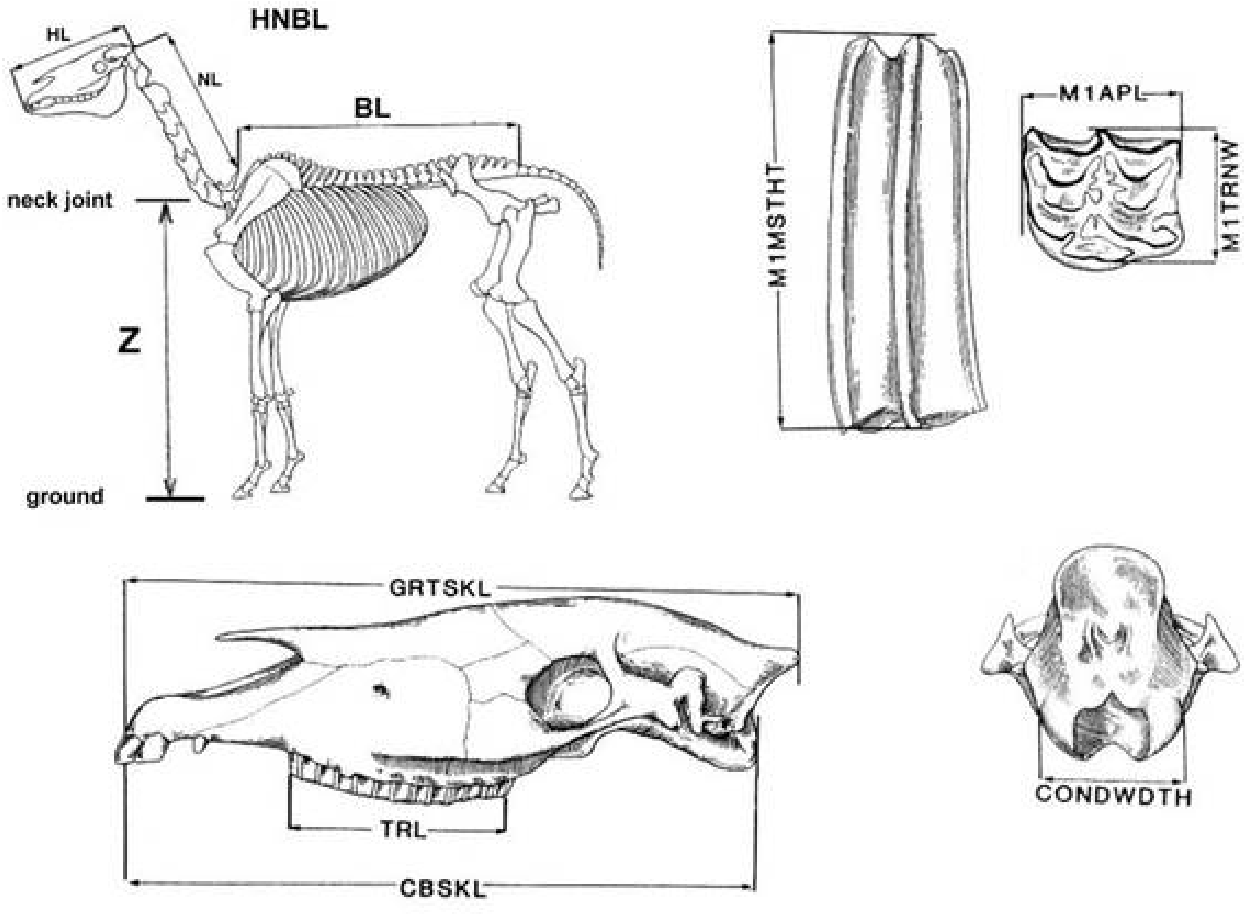
Why does this work? From the study of modern horses and horse fossils it has been shown that the ratio of the head length to the body length, the proportion of head to body through time, has shown a general trend (tendency). Yes, there are a few exceptions from the trend in the family history of the horse. That is why it is a trend.

This trend can be stated as a mathematical formula. We will use the following formula to express this general trend in horses.

formula: BL (Body Length) **= 2.4 x GRTSKL** (see diagram below)

Using the metric system, your team will be taking measurements of your fossil specimens, and calculating the estimated body length of that horse when it was alive.

The diagrams below will help to visualize what you will be measuring.



Illustrations from Fossil Horses, by Bruce J. MacFadden, 1992, Cambridge University Press

The diagrams above illustrate that scientists can measure several features on a fossil skull and use these measurements to estimate the over-all size of the horse. This is possible because studies of hundreds of thousands of horse fossils, and modern horses, have shown that as the over-all size of a horse skull increases or decreases, the rest of the body will increase or decrease in generally the same proportions. So by just finding a horse skull (or even a tooth fossil), you can not only determine what type of horse it was, but also estimate the over-all size of the horse, whether that be in length or size/mass.

FIRST QUESTION:

What is the estimated BL for each of the full-length, fossil skull specimens you have on your table?

Your team will have one or two full-length skulls on your table. Fill in the blanks below and then use the formula on the previous page to get your BL answer. Measure the skulls in centimeters, answers to the nearest tenth of a cm.

Skull Specimen # __________ GRTSKL __________cm BL _________cm

Skull Specimen # __________ GRTSKL __________cm BL _________cm

Do your math here:

(**teacher prompt:** Remind them they may only have one full skull to measure. Some teams have two and would fill out all the blanks spaces above. An easy an accurate way for them to measure a skull is to lay it down on the table and carefully put a pencil mark on the table at both ends, then pick up the skull and measure the distance between marks, then erase the marks.)

(**brief answers:**

FAM 60700 … GRTSKL = 45.7cm … BL= 109.7cm
FAM 60300 … GRTSKL = 31.2cm … BL= 74.9cm
FAM 60800 … GRTSKL = 40.9cm … BL= 98.2cm
JODA 1086 … GRTSKL = 21.7cm … BL= 52.8cm
AMNH 4832 … GRTSKL = 13.5cm … BL= 32.4cm
LACM 1863 … GRTSKL = 59.7cm … BL= 143.3cm

Note: BL is a potential indicator of speed in grazing horses, and use of BL will be more apparent in the LAB 3 exercises.)

SECOND QUESTION: (two-parts)

Refer to the previous horse diagram. After measuring many fossils of “grazing” horses, a scientist hypothesizes that the sum of the head length and neck length was equal to or greater than the length “Z” for all of the fossil horses studied. So far, the study data supports this hypothesis.

What reason(s) could explain why the HL + NL was never less than “Z” in the measurements of fossils of *grazing* horses, and does a predator have anything to do with your answer?

Write your answer here:

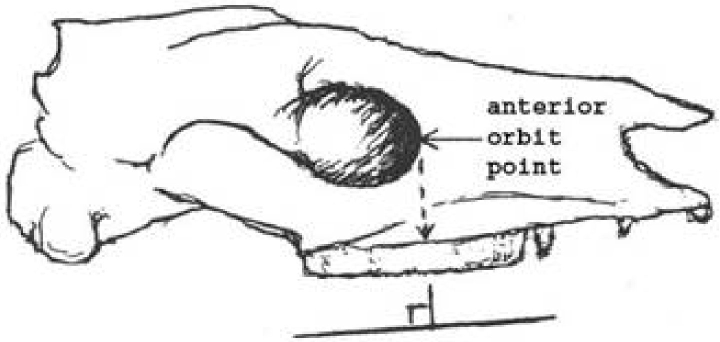
(**teacher prompt:** To help students think this out, tell them not to think of tame horses that may live around them. Have them envision a wild herd of zebra out on the grasslands of Africa, and what an individual zebra would be worried about day-to-day.)

(**brief answers:** The key word in the question is “grazing.” These types of horses are built more for speed than earlier browsing type horses. When talking about evolution it is best to focus on the various types of modern zebras, as example to students, rather than our domesticated horses.

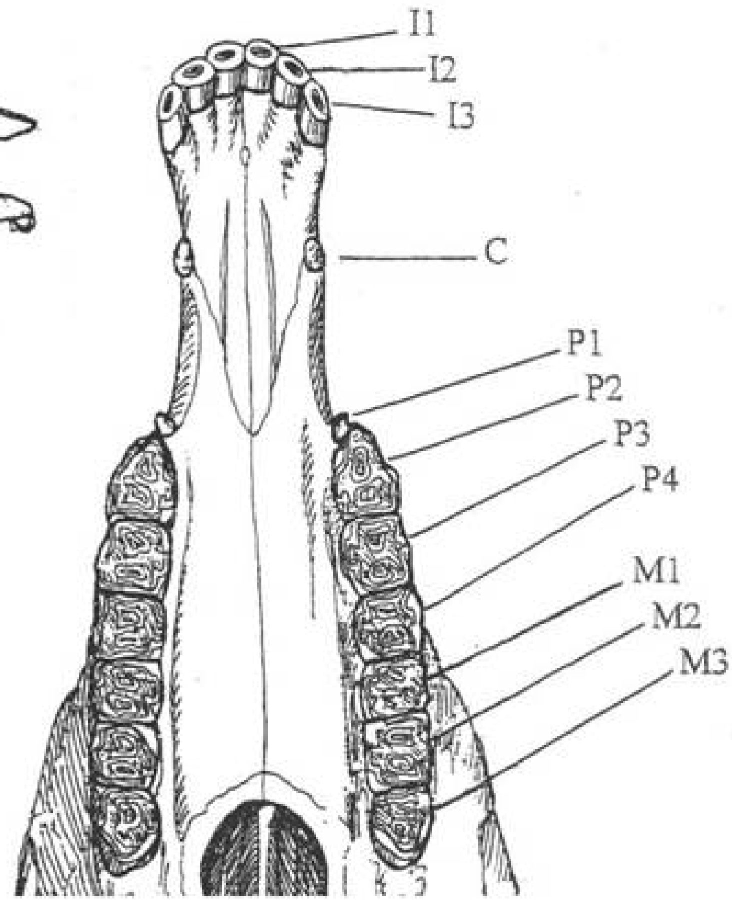
If the HL + NL were shorter than the length Z the horse would not be able to reach down and graze grasses without having to bend its leg joints, separate its front legs a bit, or kneeling or laying down. If HLNL is equal to or longer than Z the horse can graze standing erect. Also, think of the energy a grazer would waste if it stooped to eat grass (not much in one spot) stood up, walked a bit to new grass, stooped, ate, then got up again, moved to a new spot of grass ... over and over. A horse can walk and eat easily, much like a lawn mower moving across the land.

Standing erect while grazing gives the horse an advantage over those animals that must stoop to eat. [Again, think of a herd of zebras.] Horses first try to escape predators by racing away. Eating in the standing position, ready for take off, is an advantage [they also sleep standing up]. Over time a predator [lion] would be much more likely to go after those horses that needed to stoop a bit to eat, the horse being in an awkward starting position for racing away from the predator. [A good example of this is the giraffe, which browses foliage from the higher parts of trees. When this high foliage is sparse the giraffe must eat low scrubs and grasses which it cannot reach without spreading its legs wide apart. In that position it is vulnerable to predators.]

Over time the predator weeds out the easier prey to catch, and the genes from those animals are not passed on into the herd population. This also eliminates the short-necked horses from the fossil record as they are mostly consumed.)



I(incisor) C(canine) P(premolar) M(molar)



If you remember from the short film on horse evolution, the film indicated that over time the eye socket (orbit) of the skull was located further toward the rear (posterior) of later skulls. Relative to the teeth the eye socket positioned further to the rear ending up posterior to the molars.

The anterior orbit point is the eye orbit point closest to the nose.

THIRD QUESTION:

For each full-skull specimen on your table, what is the position of the "Anterior Orbit Point" (AOP) over the teeth?

To get your answers do the following. Find the anterior orbit point for each skull. Imagine the row of teeth as a straight line (see diagram above). Next, imagine a line drawn from the anterior orbit point down to the row of teeth that intersects that line at a ninety degree angle. Where is that intersection point in terms of what tooth, or teeth?

Your answers should be as precise as to which half of a tooth, or where two teeth meet.

An example … Specimen ID# <u>AMNH 555</u> AOP <u>front half of M3</u>

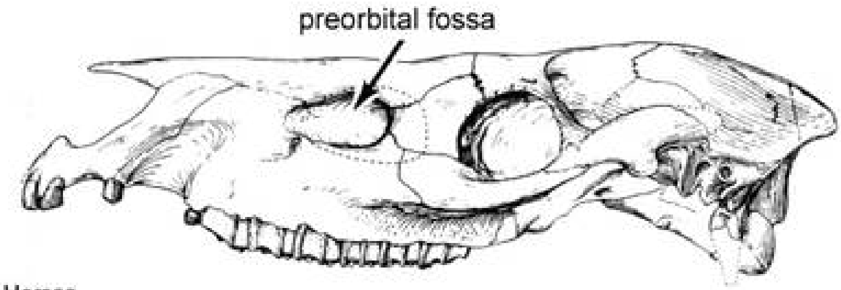
Write your answers in the spaces below.

Your Specimen ID# ____________ AOP ______________

Your Specimen ID# ____________ AOP ______________

You will have either one or two full-skull specimens at your table.

(**teacher prompt**: You may want to watch the student reactions as they try and figure where the eye orbit is located on the skull. Many of the skulls have fossae, or pits, anterior to the eye orbit. Students may think these are the eye orbits and measure from the wrong location on the skull. On some of the skulls the fossae, or pits, do look exactly like eye orbits.



from Fossil Horses

The purpose of these fossae are not yet clear, though the most likely explanation is that they serve as sites for origin of the snout and lip muscles, bone surface being where muscle attaches. The more bone surface available at a site the more muscle can be attach. On some of the skulls you can see a large groove leading from the fossa to the canine tooth, lip area, perhaps where the long muscle fit in.

Another possibility is that the fossa was filled with a scent gland of some type. Many modern deer have such glands and skull pits, but modern horses do not.)

(**brief answers:** The following are the location of the "Anterior Orbit Point" over the row of teeth, by specific tooth location.

FAM 60800 = rear half M3 **FAM 60300** = M2/M3 line **JODA 1086** = M1/M2 line
LACM 1863 = behind M3 **FAM 60700** = front half M2 **AMNH 4832** = rear half M1

Did not have to, but if they measured the partial skull …**AMNH 8174** = M2/M3 line

STOP … This is the end of Section One.

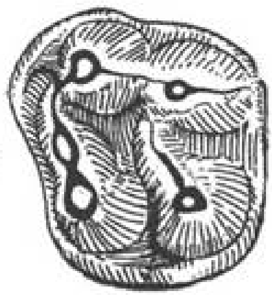
LAB 2 – Section Two (15 minutes):

This section will be conducted at the same table. Stay put, do not move.

Tooth Patterns Tell Time! Based upon literally tons of fossil evidence, the (ridgeline) patterns that evolved on the surface of horse teeth have become more complex over time. These patterns are great indicators of what type of horse you have and where the horse fits into the 55 million-year-old family tree of horse.

These two examples may help give you an idea of the change in tooth pattern complexity over time. Drawn from actual horse fossil teeth, the diagram on the left is from a very early horse molar, while the one on the right is from a recent member of the horse family tree. Both of these horse species evolved in North America and are now extinct.

scale 3 to 1



an ancient horse tooth pattern

scale 1 to 1

a modern horse tooth pattern

Scientists need to be able to recognize fossil tooth patterns which help them to identify different types of horses that lived over time. Sometimes all they have is a sketch of a tooth pattern to work from.

You will now study the patterns from the fossil teeth you have on your table before you, using all four specimens on your table.

FOURTH QUESTION:

Based upon your observations of teeth patterns, in what chronological order would you place these specimens in time from ancient to most recent?

To do this, look at the ridgeline patterns on the teeth of all four of the horse fossil specimens before you. Compare the teeth from specimen to specimen. Even compare similar individual teeth between specimens, such as comparing the M2s.

On the full skulls, you should be able to determine what types of teeth are present, from incisors to molars. Some of you fossil specimens have just a partial skull or jaw, or just a few teeth. On the list that follows you will know which teeth you have on the fossil specimens at your table for more precise comparisons between teeth, such as comparing M2s or P3s, etc., between specimens.

Types of Teeth From the Non-Skull Horse Specimens

JODA 4664 / left maxilla, M1-M

UCMP 82485 / left maxilla, M1-M3

UCMP 82497 / right maxilla, M1- M3

UCMP 68499 / left maxilla, P3 – M1, M3

UCMP 63617 / left maxilla, P4 - M2

UCMP 114476 / right dentary, M1 - M2

UCMP 114475 / right maxilla, P2 - M2

UCMP 121890 / right maxilla, P2 - P4

JODA 3363 / left maxilla, P2 - M3; right maxilla, P2, P4 - M3

Maxilla means from the skull palate. *Dentary* means from the jawbone, or mandible.

Now, carefully examine each of your four fossil specimens. Remember the film you saw on horse evolution showed that the pattern on the top of a horse tooth got more complex over time. Early in the horse family tree each horse tooth started with a simple pattern and the pattern became more complex, with more lines and swirls.

Lay the four fossil specimens out in a line on your table. One end of the line will be the most ancient, the other end the most recent. Using the teeth pattern complexity, rearrange the specimens in line so they line up from the most ancient to the most recent. Look for obvious and subtle changes, and similarities, in pattern complexity.

Write the specimen ID #'s on the lines below. If your team feels a couple of specimens are the same, write them on the same line below. Be sure and fill in your table number.

Write Your Table # Here: _____

Most Recent

Specimen #____________________

Specimen #____________________

Specimen #____________________

Specimen#____________________

Most Ancient

(**teacher prompt:** The first time the students try placing the specimens in order using tooth pattern complexity as a guide can be frustrating. They may not know what pattern complexity means.

You may need to quickly review with the students the basic difference between grazing teeth and browsing teeth. The browsers ate soft leaves and twigs by nipping them then mashing and chopping the soft plants between molars with more of an up and down motion. Feel the top of an ancient browser's tooth with your finger and you will feel peak-like points, and there will be deep valleys. Feel the top of a modern horse grazer's tooth and it will feel flat across the whole top, no points, with many fingerprint-like ridges, for grinding grasses with a side-to-side motion. Of course the teeth had to evolve from the one extreme to the other over time.

One technique to show them what to look for is to take one of the teeth specimens and bite your wrist!

Press the teeth into the skin of your wrist for several seconds and look at the pattern it makes in your skin. The pattern should stay visible for several minutes *[true story: One student once using the skin bite marks to try and get out of a later class. He showed the teacher what he said was a skin rash and said he needed to see the nurse.].* Have the students ignore the depth of the tooth valleys, and valley bottom lines. Focus on the top-most patterns of the teeth.

(**brief answer:** See the answers for all the tables at the end of Section 6.)

FIFTH QUESTION (for CIM/CAM students):

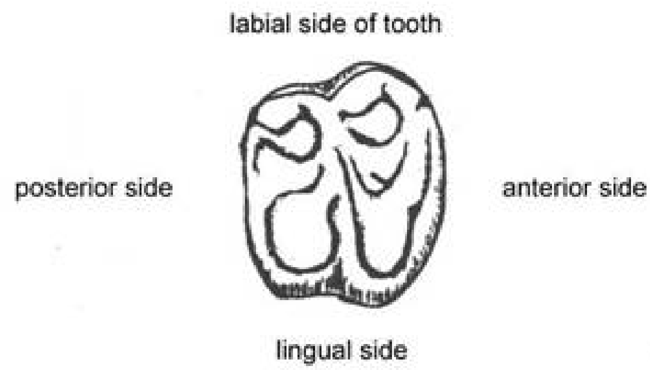
Does the tooth pattern below match any of the teeth on any of the specimens on your table?

See if you can identify the exact tooth on one of your fossil specimens. Only one table will have the tooth present. If the tooth drawing below does not match, put an “X” where the specimen ID# should be. The tooth is not drawn in one-to-one scale.

Write your table # here: ______

Write the specimen # here: _______________

Extra credit ... write what tooth it is (ex. P2 or M3) here: ______



(**teacher prompt:** Only one in four of the tables have the tooth specimen. You have a 75% chance of being right if you just say no. The pattern is not that complex.)

(**brief answer:** The tooth diagram was drawn from specimen # AMNH 4832, located at table #3. The tooth is the right M1.)

STOP ... This is the end of Section Two.

LAB 2 – Section Three (10 minutes):

The teacher will instruct your team to move to another table having different fossils, a table your team has not been to before. Each group will move to the next highest numbered table, with table four people moving to table one.

This activity will begin just as the previous study section began. (Déjà vu!) Wait for the teacher to give you the okay to move to the next table.

SIXTH QUESTION:

Look at the patterns on the teeth of the horse fossil specimens before you.

Based upon your observations of teeth patterns, in what chronological order would you place these specimens in time from ancient to most recent?

Write the specimen ID #'s on the lines below. If your team feels a couple of specimens are the same, write them on the same line below. Be sure and fill in your table number.

Write Your Table # Here: _____

Most Recent

Specimen #____________________

Specimen #____________________

Specimen #____________________

Specimen#____________________

Most Ancient

(**brief answer:** See the answers for all the tables at the end of Section 6.)

SEVENTH QUESTION:

Based upon information on handouts given to you, do meat-eating animals tend to have a "hypocone" on their teeth? (yes or no)

(**brief answer:** Based upon the LAB 2 – SHEET 2 information, the answer is no. Plant-eating mammals developed a hypocone, changing the top shape of the tooth from a triangle to a rectangle, increasing the surface area to better munch on plant material.)

STOP … This is the end of Section Three.

LAB 2 – Section Four (10 minutes):

This activity will begin just as the previous study period began. (What did you expect?) Wait for the teacher to give you the word to move to the next table.

EIGHTH QUESTION:

Look at the patterns on the teeth of the horse fossil specimens before you.

Based upon your observations of teeth patterns, in what chronological order would you place these specimens in time from ancient to most recent?

Write the specimen ID #'s on the lines below. If your team feels a couple of specimens are the same, write them on the same line below. Be sure and fill in your table number.

Write Your Table # Here: _____

Most Recent

Specimen #____________________

Specimen #____________________

Specimen #____________________

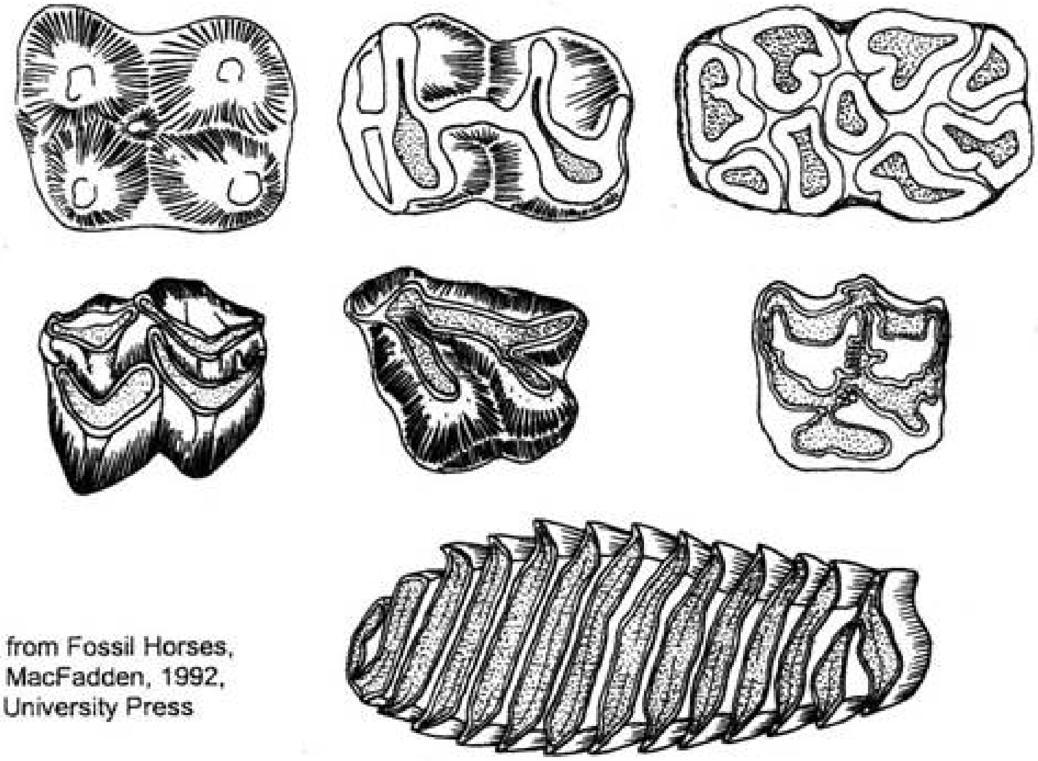
Specimen#____________________

Most Ancient

(**brief answer:** See the answers for all the tables at the end of Section 6.)

NINTH QUESTION: Now that your team has had a chance to look over a few horse fossil teeth and you have an initial idea what horse teeth patterns look like, try looking over the following teeth and answering the question.

Which one tooth below belongs to a horse?
Circle the tooth you select as the horse tooth.



Illustrations from Fossil Horses, by Bruce J. MacFadden, 1992, Cambridge University Press

(**teacher prompt:** A clue you can give out if they seem to struggle, the horse tooth they are looking for is from a modern grazing horse, not a browsing horse.)

(**brief answer:** The horse tooth is the one on the right, middle row. It shows classic tooth pattern, very squiggly, from a modern grazing horse.

The other teeth from left to right, top to bottom are from a peccary, kangaroo, warthog, deer, rhinoceros, horse, and the large rodent - capybara.)

STOP … This is the end of Section Four.

LAB 2 – Section Five (5 minutes):

This activity will begin just as the previous study period began. (Yeaaa! Last time!)

TENTH QUESTION:

Look at the patterns on the teeth of the horse fossil specimens before you.

Based upon your observations of teeth patterns, in what chronological order would you place these specimens in time from ancient to most recent?

Write the specimen ID #'s on the lines below. If your team feels a couple of specimens are the same, write them on the same line below. Be sure and fill in your table number.

Write Your Table # Here: _____

Most Recent

Specimen #____________________

Specimen #____________________

Specimen #____________________

Specimen#____________________

Most Ancient

(**brief answer:** See the answers for all the tables at the end of Section 6.)

STOP … This is the end of Section Five.

LAB 2 – Section Six (30 minutes):

Please ask the students to stay seated at their current table.

Let's Check Your Answers (the first 20 minutes)…

We are going to check the answers written down on the team leader's papers. These will be the team answers. Everyone should have written down the answers to the questions on their copy of the directions, so have your answers ready in case the team leader has written down something that is not clear.

We will answer questions 4, 6, 8, and 10 first. These questions asked for the order of the four fossils on your table from most ancient to most recent. Everyone should have gone to each of the four tables, and at each table you wrote down the table number.

(**teacher prompt:** For the younger students it is important to emphasize that putting fossils in order of time was not easy to do, this was the first time they ever did it, they were under a time restriction that made it more difficult, and they would do better the next time given all the time they needed to make the proper observation of each fossil specimen. Focus on the successes they have, especially if they can get the oldest and youngest in each group of four. Placing the middle teeth was harder.

For the older students, if it makes it more interesting, set up a competition at the start for the best science team. The winning team gets an imaginary $100,000 research grant to study fossils at John Day Fossil

Beds national Monument. Then keep score as to which team was most accurate. After all, they don't give out these grants to just anyone.)

Everyone flip to the sheet that has the four fossils from table one. Take turns letting each of the team leaders have first crack at the answers for one of the four tables. Once the team leader reads their answers out loud, ask if any other groups had a different order. Let them read the different orders. Then select the team(s) with the best order, the most accurate answers. Rarely does any team get all four tables in the same order the scientist have placed them.

Table #1 Answers: (most Recent at the top - most Ancient on the bottom)

FAM 60300
JODA 4664 ……… Close between 4664 and 3363.
JODA 3363 Look at the M3 on both to decide.
UCMP 114475

Tables #2 Answers:

FAM 60800 …….. M1 & M2 lingual-side loops
UCMP 63617 formed islands on 60800.
JODA 1086
UCMP 114476

Table #3 Answers:

LACM 1863 …….. The youngest of all 16.
UCMP 121890
UCMP 82485
AMNH 4832 ……. The oldest of all 16.

Table #4 Answers:

UCMP 82497

____

FAM 60700 & AMNH 8174 ……. Much wear on 8174. Too
UCMP 68499 close to call, a tie.

(**teacher prompt**: After you review each table and the chronological order of the four fossils on each, let the students know you will now go over the rest of the answers from the beginning.)

From the beginning of these "teacher reference" directions go over each of the remaining questions, give the answers, and hold any needed discussions. If you can, leave ten minutes for the last activity.

Putting it all together (10 minutes) … Teacher bring out LAB 2 – SHEET 4 TR.

In what order did the sixteen fossil specimens you have studied evolve over time?

Your teacher will now have the teams assemble all the fossils on one large flat area, placing them in chronological order like the "horse family tree" diagram on your handout. The particular process of assembling the four groups of fossils into one large family tree will be left up to you and the teacher. (You can bring individual or groups of fossils to the flat area, start from the most ancient and build your family tree toward the present, or go present to past, however you decide.) **Please handle the fossil replicas very carefully, as they will break.**

Your teacher has a list of the fossil specimen ID #'s (LAB 2 – SHEET 4), and the genus name of the horse for each specimen number. As each specimen is identified by name, upon your family tree diagram on the handout, write down the specimen ID # next to the genus name. Write small, as there may be more than ID # per genus name on the diagram.

All the fossil specimens, when laid out on the flat area in proper order, will tend to look like a family tree and not a straight line. Your teacher will give you some time to look this arrangement of horse fossils over. When you do, first focus your attention on the developing complexity of tooth pattern over time. Note that the earliest horses were browsers, and that the most recent horses were grazers. There was a time when browsing and grazing horses lived side-by-side on this continent, for many millions of years.

STOP … Congratulations! You have completed the entire LAB 2.

LAB 2 – SHEET 1 A Study Of Horse Fossils (student directions)

OVERVIEW: This is the primary study lab in this horse kit. Students will be able to handle sixteen horse fossils, make measurements and observations, draw conclusions to questions presented, and discuss interpretations of the data.

TIME LIMITS: This study package is designed to be conducted over the course of two 45 minute class periods. Over these two class periods there are a total of six lab sections. LAB 2 sections range from 20 to 10 minutes in length.

There are about 30 minutes of student research needed before the class lab is conducted, entailing the reading of handouts. The students will use the same handouts during the lab, and should be reminded to bring them to the lab.

STUDENT RESEARCH BEFORE CLASSROOM LAB: Before the lab is conducted in the classroom, students will need to do some basic background research, all of it reading. Have the students read and become familiar with the following LAB 2 sheets, and have them bring these sheets to the classroom lab:

- Ø LAB 2 – SHEET I (lab directions, procedures, and questions)
- Ø LAB 2 – SHEET 2 (tooth development)
- Ø For the CIM/CAM students, LAB 2 – SHEET 3 (tooth wear)
- Ø Look over the previous LAB 1 – SHEET 2 (horse family tree)

Students must bring all of the above sheets they have been given to the classroom lab.

CLASSROOM LAB WORK STARTS HERE

(Sections 1-6 to be completed over two 45 minute class periods)

LAB 2 - Section One (students have 20 minutes to complete this section):

TEAM LEADER: Start reading from here …

Please be very careful handling these breakable fossil replicas. Always use two hands when picking up and holding the larger skulls.

The team leader will read these directions and lead the group efforts. Everyone should read silently along with the leader. There are three questions in this section that need to be answered. Everyone on the team should jot down answers to questions on their personal copies. The team leader's copy and answers will represent the group in later discussions.

Work as a team. Everyone should get involved, and open discussion in your group is encouraged. Share your observations. Be skeptical. If you do not agree, say so and discuss it briefly. That is what scientists do.

Only time will limit your thoughts. You don't have much time to do this lab, so don't waste time. Try and get the most accurate answer your team can come up with, then write it down.

All the teams will start each lab section at the same time. Keep going until the directions tell you to stop. If you finish early do not move on to the next section.

The table you are seated at has a number. Check the fossil specimen numbers on your table against the following list to be sure you have the right fossils at your table.

Table #1: FAM 60300, JODA 3363, JODA 4664, UCMP 114475

Table #2: FAM 60800, JODA 1086, UCMP 114476, UCMP 63617

Table #3: AMNH 4832, LACM 1863, UCMP 82485, UCMP 121890

Table #4: FAM 60700, AMNH 8174, UCMP 68499, UCMP 82497

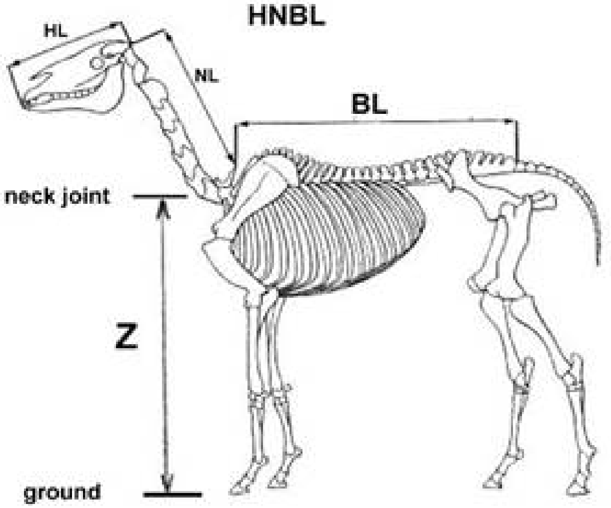
ESTIMATING HORSE SIZE ACTIVITY: The body length of a horse may be used to estimate the general size or mass of the horse. In this lab activity we do not have the fossil bodies of horses, but you will be able to estimate the body length (BL) of a horse fossil by measuring another part of the fossilized body, the length of the skull.

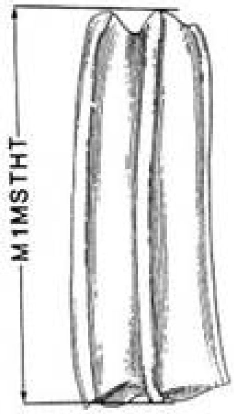
> Why does this work? From the study of modern horses and horse fossils it has been shown that the ratio of the head length to the body length, the proportion of head to body through time, has shown a general trend (tendency). Yes, there are a few exceptions from the trend in the family history of the horse. That is why it is a trend.
>
> This trend can be stated as a mathematical formula. We will use the following formula to express this general trend in horses.

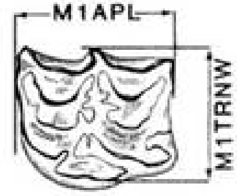
formula: **BL** (Body Length) **= 2.4 x GRTSKL** (see diagram below)

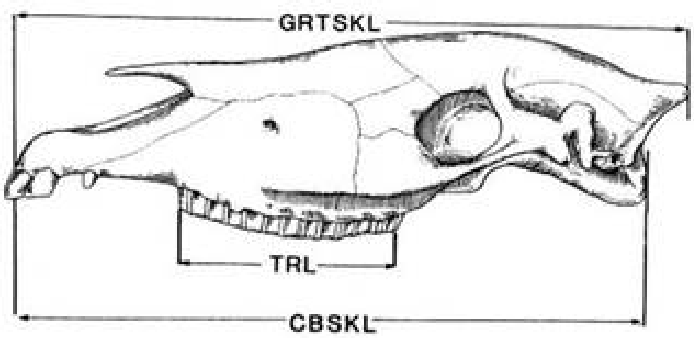
Using the metric system, your team will be taking measurements of your fossil specimens, and calculating the estimated body length of that horse when it was alive.

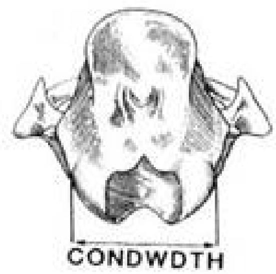
The diagrams that follow will help to visualize what you will be measuring.











Illustrations from Fossil Horses, by Bruce J. MacFadden, 1992, Cambridge University Press

The diagrams above illustrate that scientists can measure several features on a fossil skull and use these measurements to estimate the over-all size of the horse. This is possible because studies of hundreds of thousands of horse fossils, and modern horses, have shown that as the over-all size of a horse skull increases or decreases, the rest of the body will increase or decrease in generally the same proportions. So by just finding a horse skull (or even a tooth fossil), you can not only determine what type of horse it was, but also estimate the over-all size of the horse, whether that be in length or size/mass.

FIRST QUESTION:

What is the estimated BL for each of the full-length, fossil skull specimens you have on your table?

Your team will have one or two full-length skulls on your table. Fill in the blanks below and then use the formula on the previous page to get your BL answer. Measure the skulls in centimeters, answers to the nearest tenth of a cm.

Skull Specimen # __________ GRTSKL __________cm BL _________cm

Skull Specimen # __________ GRTSKL __________cm BL _________cm

Do your math here:

SECOND QUESTION: (two-parts)

Refer to the previous horse diagram. After measuring many fossils of “grazing” horses, a scientist hypothesizes that the sum of the head length and neck length was equal to or greater than the length “Z” for all of the fossil horses studied. So far, the study data supports this hypothesis.

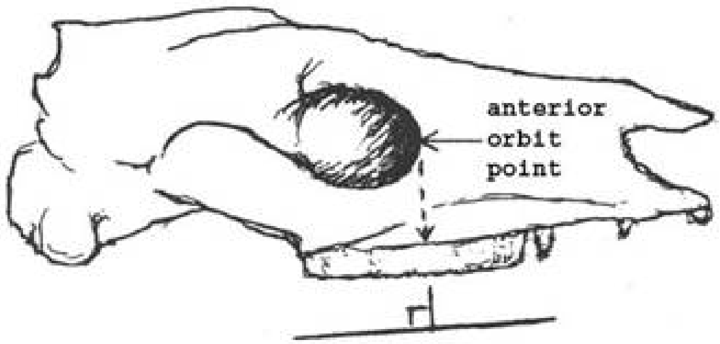
What reason(s) could explain why the HL + NL was never less than “Z” in the measurements of fossils of *grazing* horses, and does a predator have anything to do with you answer?

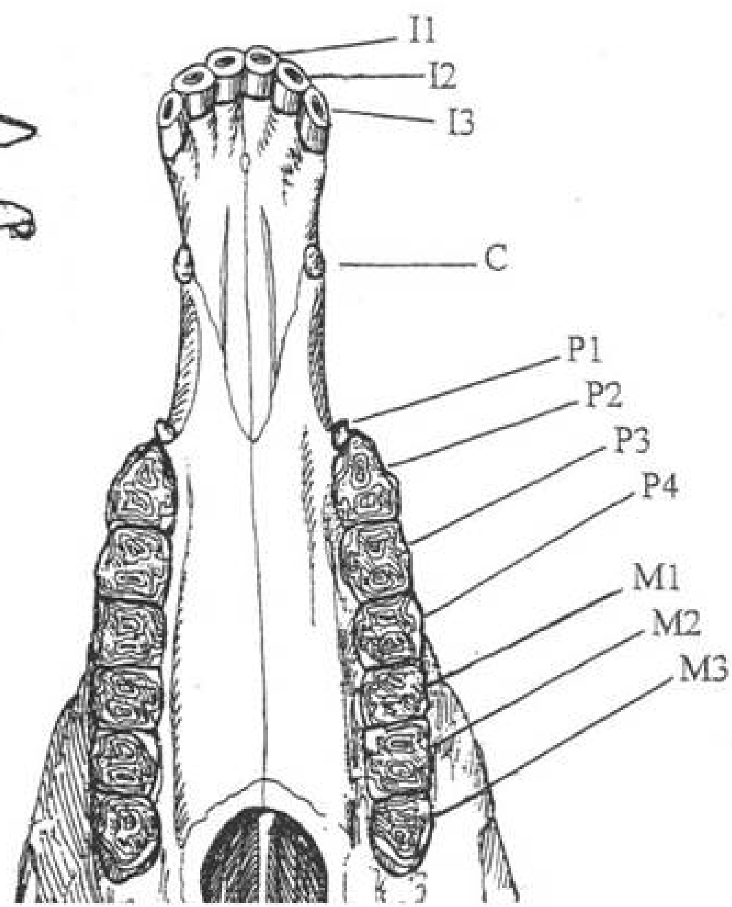
Write your answer here:

THIRD QUESTION:

For each full-skull specimen on your table, what is the position of the “Anterior Orbit Point” (AOP) over the teeth?

I(incisor) C(canine) P(premolar) M(molar)





If you remember from the short film on horse evolution, the film indicated that over time the eye socket (orbit) of the skull was located further toward the rear (posterior) of later skulls. Relative to the teeth the eye socket positioned further to the rear ending up posterior to the molars.

The anterior orbit point is the eye orbit point closest to the nose.

To get your answers do the following. Find the anterior orbit point for each skull. Imagine the row of teeth as a straight line (see diagram above). Next, imagine a line drawn from the anterior orbit point down to the row of teeth that intersects that line at a ninety degree angle. Where is that intersection point in terms of what tooth, or teeth?

Your answers should be as precise as to which half of a tooth, or where two teeth meet.

An example … Specimen ID# AMNH 555 AOP front half of M3

Write your answers in the spaces below.

Your Specimen ID# ____________ AOP ______________

Your Specimen ID# ____________ AOP ______________

You will have either one or two full-length skull specimens at your table.

STOP … This is the end of Section One.

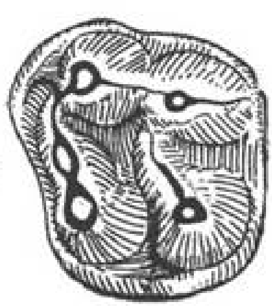
LAB 2 – Section Two (15 minutes):

This section will be conducted at the same table. Stay put, do not move.

Tooth Patterns Tell Time! Based upon literally tons of fossil evidence, the (ridgeline) patterns that evolved on the surface of horse teeth have become more complex over time. These patterns are great indicators of what type of horse you have and where the horse fits into the 55 million-year-old family tree of horse.

These two examples may help give you an idea of the change in tooth pattern complexity over time. Drawn from actual horse fossil teeth, the diagram on the left is from a very early horse molar, while the one on the right is from a recent member of the horse family tree. Both of these horse species evolved in North America and are now extinct.

scale 3 to 1



an ancient horse tooth pattern

scale 1 to 1

a modern horse tooth pattern

Scientists need to be able to recognize fossil tooth patterns which help them to identify different types of horses that lived over time. Sometimes all they have is a sketch of a tooth pattern to work from.

You will now study the patterns from the fossil teeth you have on your table before you, using all four specimens on your table.

FOURTH QUESTION:

Based upon your observations of teeth patterns, in what chronological order would you place these specimens in time from ancient to most recent?

To do this, look at the ridgeline patterns on the teeth of all four of the horse fossil specimens before you. Compare the teeth from specimen to specimen. Even compare similar individual teeth between specimens, such as comparing the M2s.

On the full skulls, you should be able to determine what types of teeth are present, from incisors to molars. Some of you fossil specimens have just a partial skull or jaw, or just a few teeth. On the list that follows you will know which teeth you have on the fossil specimens at your table for more precise comparisons between teeth, such as comparing M2s or P3s, etc., between specimens.

<u>Types of Teeth ---From the (Non-Skull) Specimens at Your Table--</u>

JODA 4664 / left maxilla, M1-M

UCMP 82485 / left maxilla, M1-M3

UCMP 82497 / right maxilla, M1- M3

UCMP 68499 / left maxilla, P3 – M1, M3

UCMP 63617 / left maxilla, P4 - M2

UCMP 114476 / right dentary, M1 - M2

UCMP 114475 / right maxilla, P2 - M2

UCMP 121890 / right maxilla, P2 - P4

JODA 3363 / left maxilla, P2 - M3; right maxilla, P2, P4 - M3

Maxilla means from the skull palate. *Dentary* means from the jawbone, or mandible.

Next, carefully examine each of your four fossil specimens. Remember the film you saw on horse evolution showed that the pattern on the top of a horse tooth got more complex over time. Early in the horse family tree each horse tooth started with a simple pattern and the pattern became more complex, with more lines and swirls.

Lay the four fossil specimens out in a line on your table. One end of the line will be the most ancient, the other end the most recent. Using the teeth pattern complexity, rearrange the specimens in line so they line up from the most ancient to the most recent. Look for obvious and subtle changes, and similarities, in pattern complexity.

Write the specimen ID #'s on the lines below. If your team feels a couple of specimens are the same, write them on the same line below. Be sure and fill in your table number.

Write Your Table # Here: _____

Most Recent

Specimen #____________________

Specimen #____________________

Specimen #____________________

Specimen#____________________

Most Ancient

FIFTH QUESTION (for CIM/CAM students):

Does the tooth pattern below match any one of the teeth on any one of the specimens on your table?

See if you can identify the exact tooth on one of your fossil specimens. Only one table will have the tooth present. If the tooth drawing below does not match any fossil teeth at your table, put an "X" where the specimen # should be. The tooth below is not drawn in one-to-one scale.

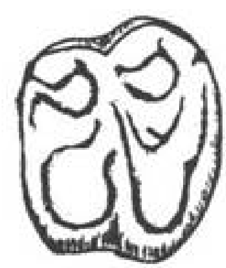
Write your table # here: ______

Write the specimen # here: ______________

Extra credit ... write what tooth it is (ex. P2 or M3) here: ______

labial side of tooth

posterior side



anterior side

lingual side

STOP ... This is the end of Section Two.

LAB 2 – Section Three (10 minutes):

The teacher will instruct your team to move to another table to do this section. Each group will move to the next highest numbered table. The table #4 people move to table #1.

The activity at the your new table will begin just as the previous study section began.

SIXTH QUESTION:

Look at the patterns on the teeth of the horse fossil specimens before you.

Based upon your observations of teeth patterns, in what chronological order would you place these specimens in time from ancient to most recent?

Write the specimen ID #'s on the lines below. If your team feels a couple of specimens are the same, write them on the same line below. Be sure and fill in your table number.

Write Your Table # Here: _____

Most Recent

Specimen #____________________

Specimen #____________________

Specimen #____________________

Specimen#____________________

Most Ancient

SEVENTH QUESTION:

Based upon information on handouts given to you, do meat-eating animals tend to have a "hypocone" on their teeth? (yes or no)

Your Answer: _______

STOP … This is the end of Section Three.

LAB 2 – Section Four (10 minutes):

Wait for the teacher to give you the word to move to your new table.

EIGHTH QUESTION:

Look at the patterns on the teeth of the horse fossil specimens before you.

Based upon your observations of teeth patterns, in what chronological order would you place these specimens in time from ancient to most recent?

Write the specimen ID #'s on the lines below. If your team feels a couple of specimens are the same, write them on the same line below. Be sure and fill in your table number.

Write Your Table # Here: _____

Most Recent

Specimen #____________________

Specimen #____________________

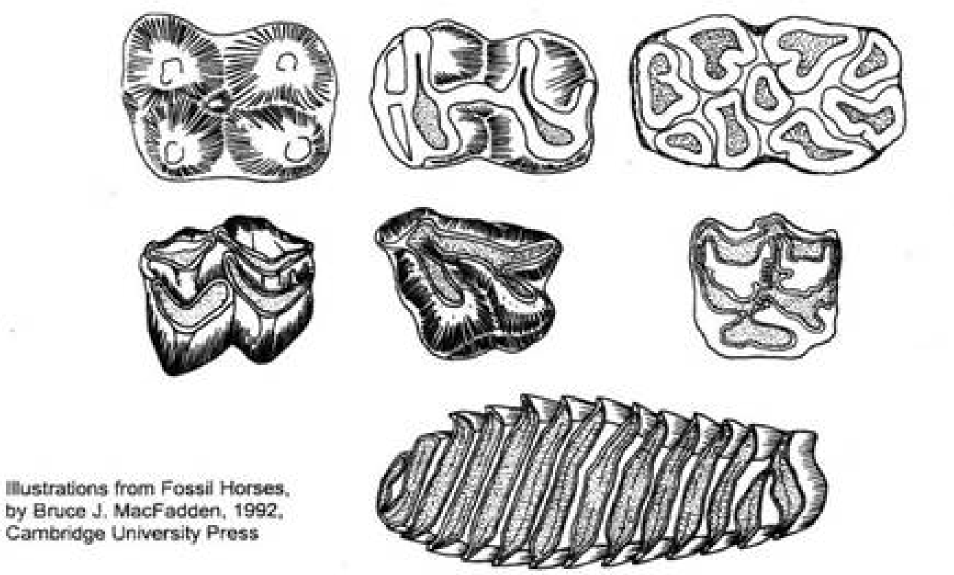
Specimen #____________________

Specimen#____________________

Most Ancient

NINTH QUESTION: Now that your team has had a chance to look over a few horse fossil teeth, try looking over the following teeth and answering the question.

Which one tooth below belongs to a horse? (Circle or check mark the tooth you select.)



STOP … This is the end of Section Four.

LAB 2 – Section Five (5 minutes):

This activity will begin just as the previous study period began. (Yeaaa! Last time!)

TENTH QUESTION:

Look at the patterns on the teeth of the horse fossil specimens before you.

Based upon your observations of teeth patterns, in what chronological order would you place these specimens in time from ancient to most recent?

Write the specimen ID #'s on the lines below. If your team feels a couple of specimens are the same, write them on the same line below. Be sure and fill in your table number.

Write Your Table # Here: _____

Most Recent

Specimen #____________________

Specimen #____________________

Specimen #____________________

Specimen#____________________

Most Ancient

STOP … This is the end of Section Five.

LAB 2 – Section Six (30 minutes):

Please stay seated at your current table. Please follow your teacher's directions.

Let's Check Your Answers (the first 20 minutes)…

We are going to check the answers written down on the team leader's papers. These will be the team answers. Everyone should have written down the answers to the questions on their copy of the directions, so have your answers ready in case the team leader has written down something that is not clear.

Putting it all together (10 minutes) …

You will find out the order that all sixteen fossil specimens lived through time.

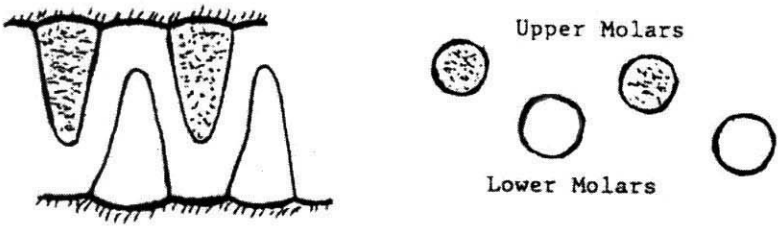
STOP … Congratulations! You have completed all of LAB 2.

LAB 2 - SHEET 2

Reptilian to Mammal Tooth Development

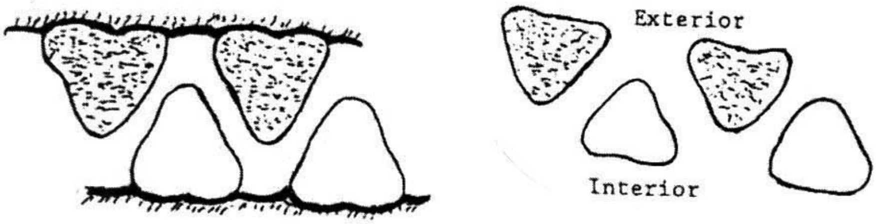
Reptilian Teeth:

(looking from above)



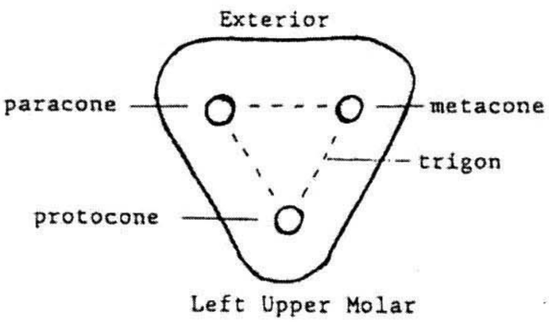
1. Note the single cusp (tooth cone with point) teeth with no crown (crown-shape at top of tooth). There is no overlap on occlusion (teeth biting contact).

Primitive Mammal Teeth:



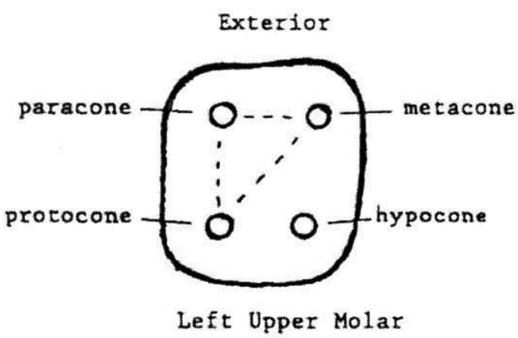
2. Note development of triangular (tribosphenic) tooth shape. Upper and lower teeth have reverse triangles.

Primitive Mammal Tooth Development:



3. Each of the triangular teeth would evolve three points, or cusps (cones). Connecting the points of the three cones would form a triangle. This triangle is called the trigon for upper teeth, and trigonid for the lower teeth.

Modern Herbivorous Mammal Tooth:



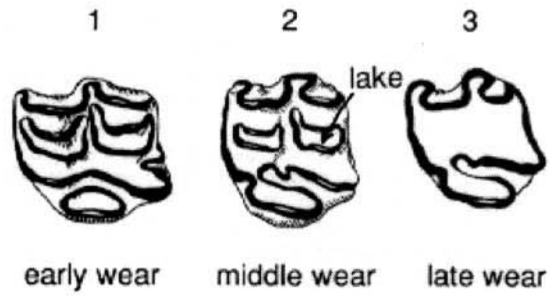
4. The triangular shape becomes quadrangle (four sided). An additional cone develops. Upper and lower teeth are over-lapped, and on occlusion allow crushing and grinding. The cones on the lower teeth have differing names. (Carni-vourous mammals tended to keep the trigon/trigonid tooth form, with variations)

Drawings adapted from the book <u>Mammal Evolution an Illustrated Guide</u> by R.J.G. Savage & M.R. Long.

LAB 2 - SHEET 3 (For CIM & CAM students to read before the lab.)

Variation, or why are horse teeth so ditticult to identify?

Variation is a characteristic of all life and demonstrates that no two individuals are exactly the same in their features and attributes. Variation can result from several sources. **Taxonomic** variations are those differences that allow us to distinguish different groups or species (e.g., the dental patterns of different species of fossil horses). **Geographic** variation might result in differences between populations of the same species from different regions (e.g., different hair color in the same species of squirrel from different areas). **Sexual** variation (also called dimorphism) are those differences between the sexes of the same species (e.g., as a rule in mammals, males are generally larger than females). Although fossil horses display all of these variations, in this article we will concentrate on another type, **ontogenetic** variation, which are those differences that occur during the lifetime of an individual (e.g., the increase in size from a baby to a mature adult, or the change in dental patterns of teeth.) This is the first part of a series in which we will discuss each of these types of variation. In keeping with the general theme of this issue on Bone Valley horses, we will use the species *Pseudhipparion simpsoni* to illustrate some ontogenetic changes that occur in the dentition throughout the lifetime of an individual.



During early wear stages, the upper teeth of Bone Valley *Pseudhippanon* exhibit a dental pattern with clearly defined enamel folds and an isolated protocone (see figure here; also see article above on Bone Valley horses). Specimens like this one represent animals that died as juveniles. In middle wear stages the dental pattern changes and the protocone becomes connected to the protoloph and the enamel lakes become smaller. In late wear stages, represented by those individuals that died in old age, the dental pattern simplifies and the enamel lakes are lost in most cases. Thus the stage of wear, which represents the time at which an individual died, has a profound impact on the dental pattern. Earlier workers were less aware of ontogenetic changes that occurred in fossil horse teeth. As a result, different species s ometimes were named for different ontogenetic stages. These were recognized later as pertaining to the same species.

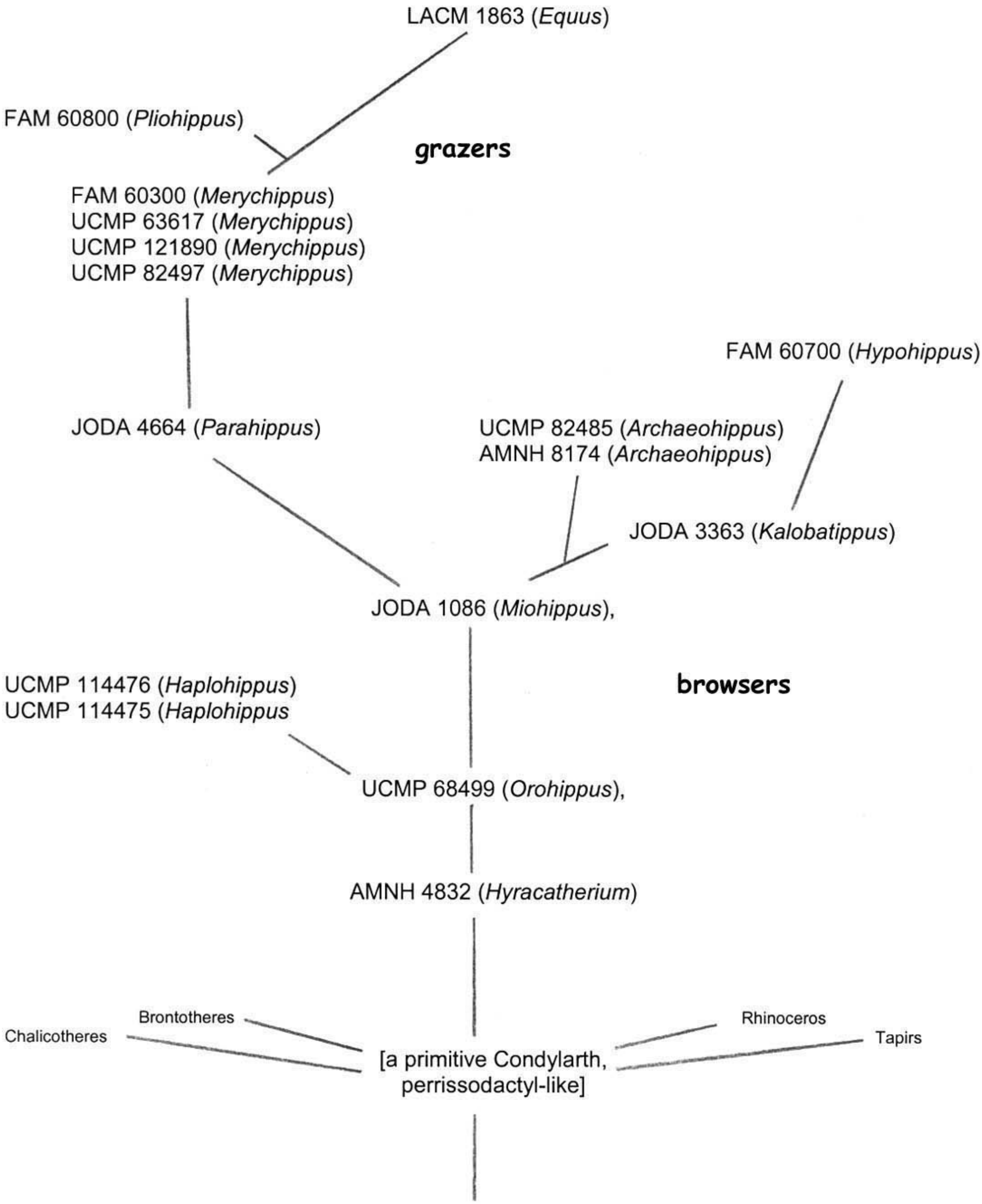
In summary, ontogenetic variation can cause problems in identifying fossil horse teeth because the dental pattern can change even within the same species depending upon the age at which the animal died. We are lucky, however, because few fossil horses change as much as do specimens of Bone Valley *Pseudhippaiion*. We nevertheless must take ontogenetic variation into account when identifying fossil horse teeth--it is just one reason why individual horse teeth are difficult to identify for both the amateur and professional, too!

From: The <u>Pony Express</u> newsletter, Univ. of Florida, Vol. 1, Number 3, Sept. 1992

LAB 2 - SHEET 4

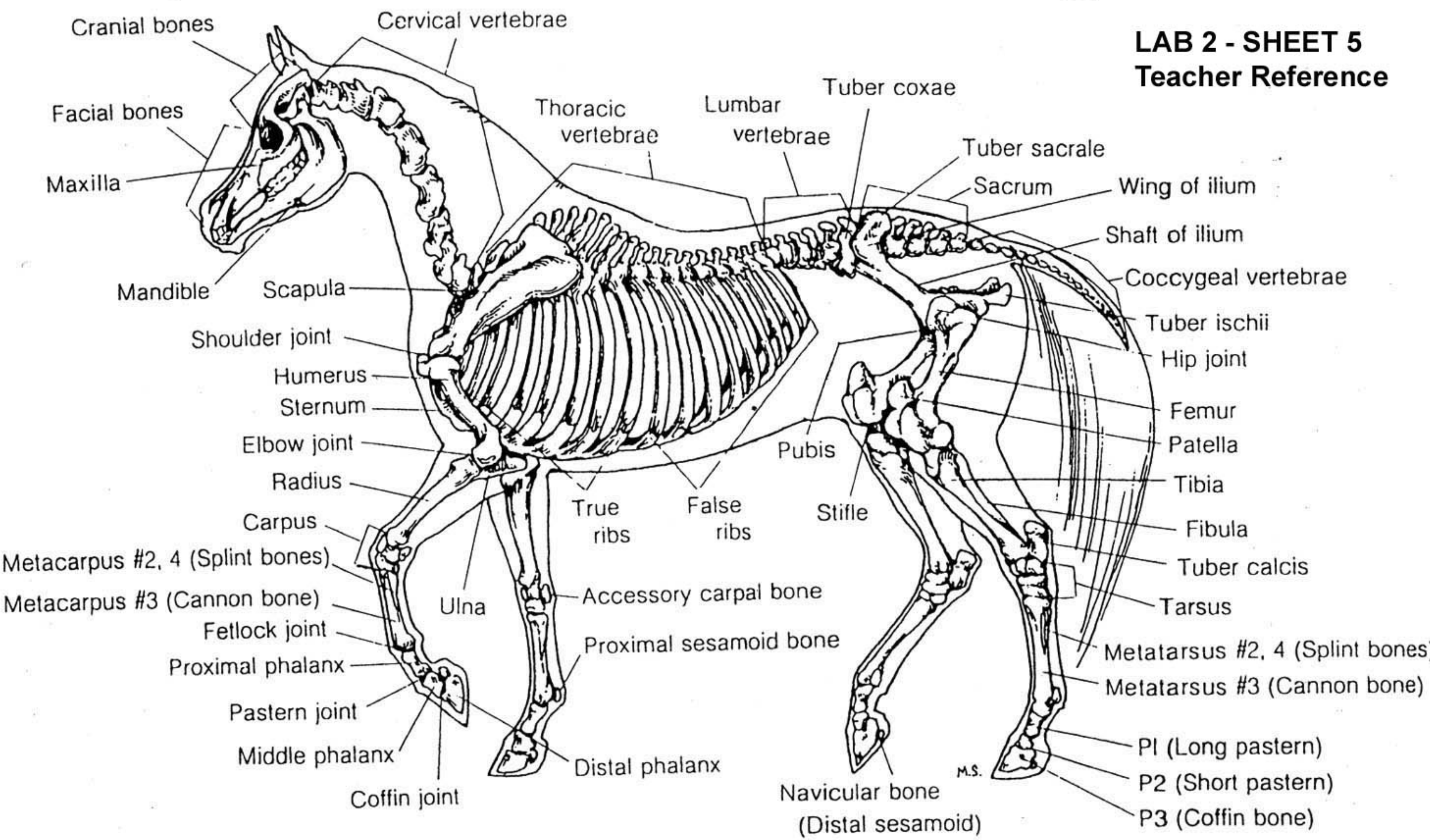
TEACHER REFERENCE

Horse Kit Family Tree (using the 16 specimens in the kit)

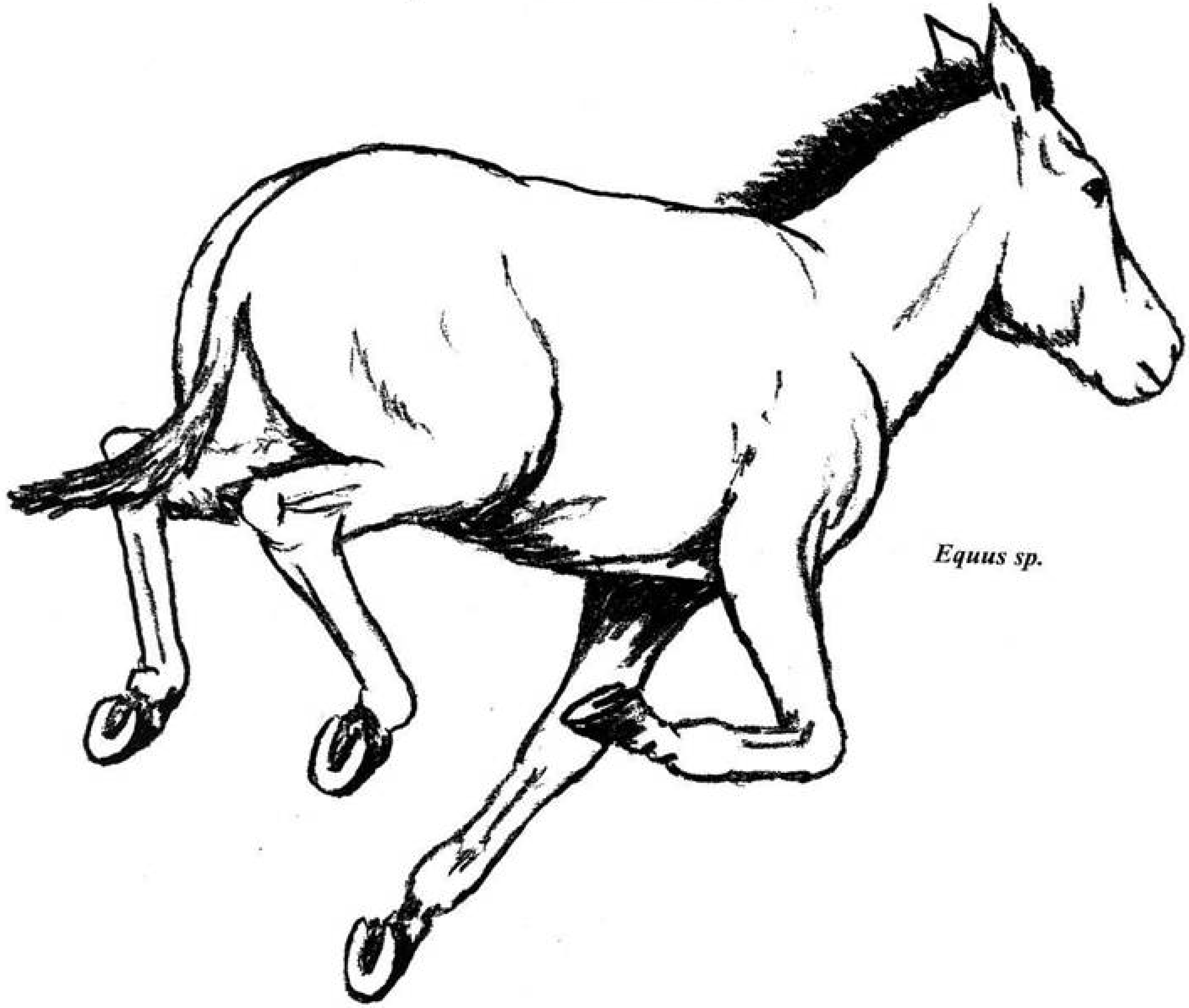


SKELETON OF THE HORSE

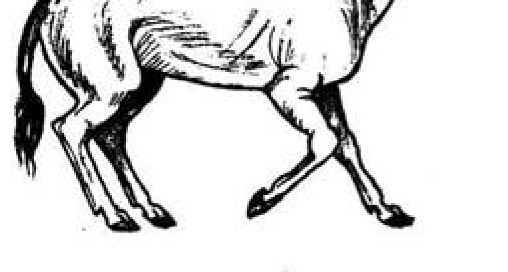
LAB 2 - SHEET 5
Teacher Reference



ORIGINAL FOR COPIES - Drawings are to relative scale to each other.



Equus sp.



Hyracotherium sp.

LAB 2 - Sheet 6 (page 1 of 3)

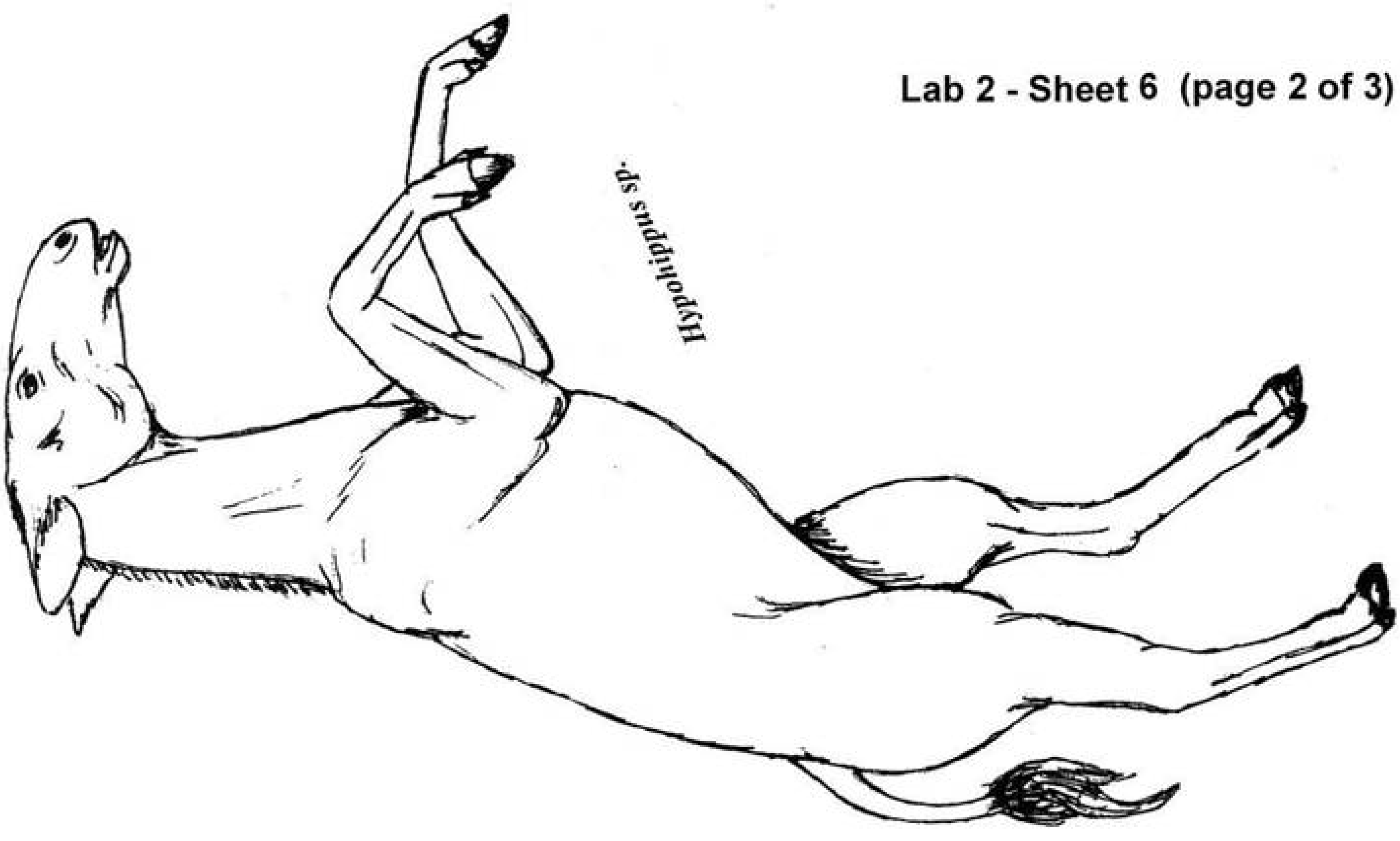
There are eight drawings of ancient horses on three pages. Make copies of the drawings and then cut them out. As the class lays out the fossils in a family tree, place the horse drawings next to the fossils they represent. The fossil drawings are to scale relative to each other.

ORIGINAL FOR COPIES -

Drawings are to relative scale to each other.

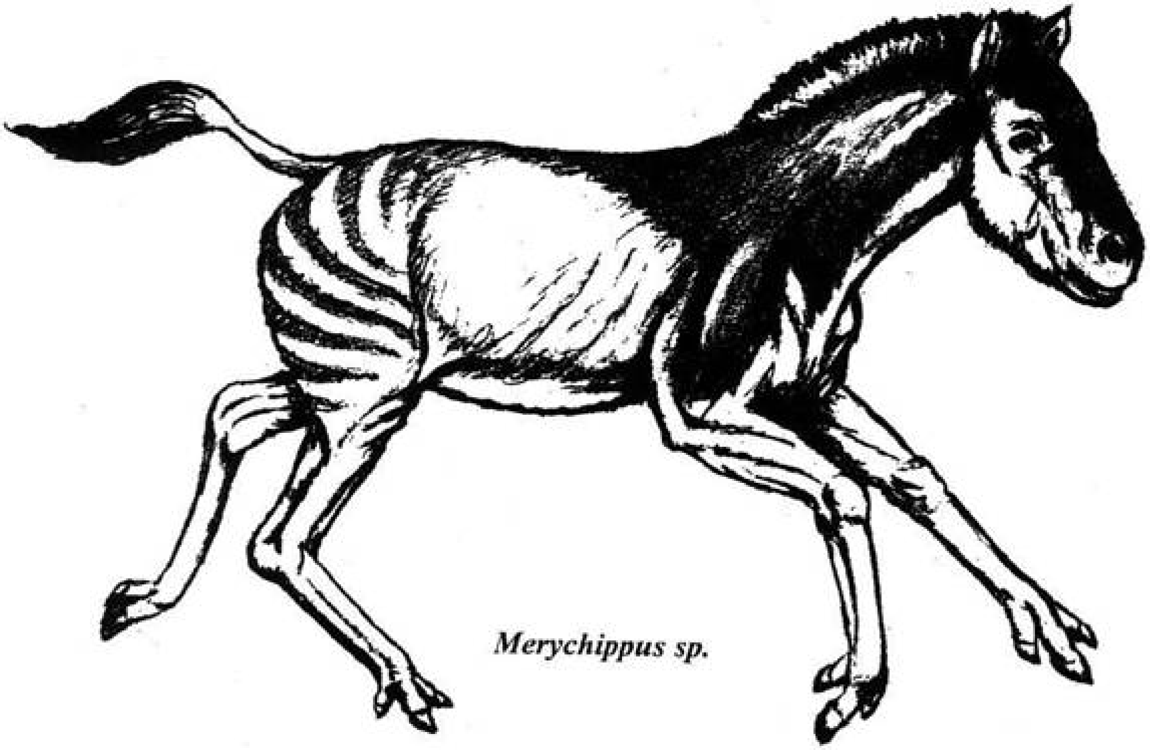
Pliohippus sp.

Lab 2 - Sheet 6 (page 2 of 3)



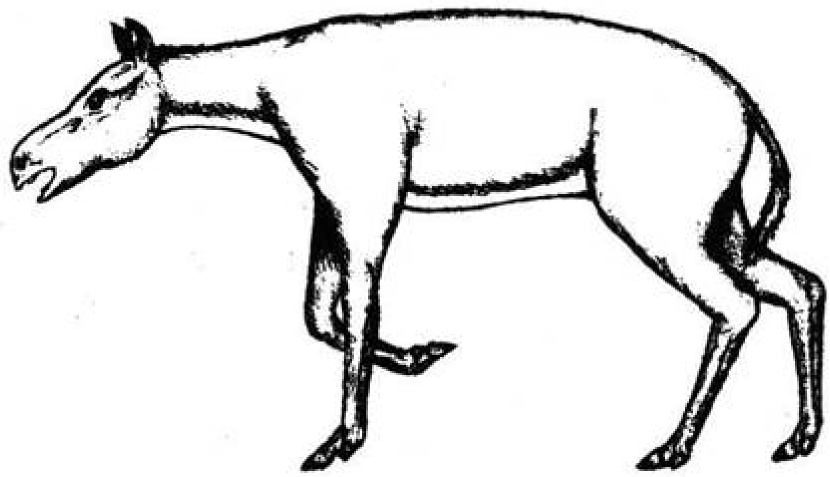
Hypohippus sp.

ORIGINAL FOR COPIES - Drawings are to relative scale to each other.



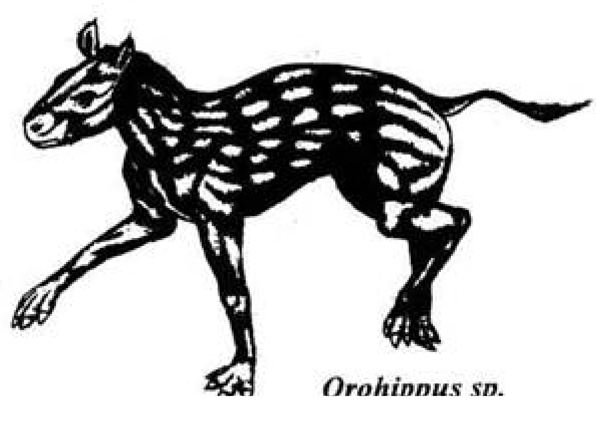
Merychippus sp.

Lab 2 - Sheet 6 (page 3 of 3)



Archaeohippus sp.

Miohippus sp.



Orohippus sp.

Orohippus sp.

LAB 2 – TEACHER REFERENCE

The internet sites listed below, with links, provide diverse research information for the teacher to prepare themselves before presenting the labs in the horse kit. Students involved in CIM & CAM could also be referred to these sites for research and lab preparation. The "Horses In Cyberspace" site is a wonderful place for students to explore.

LAB 2 Preparation: Teachers should definitely read the four articles listed in **bold and underlined** below in preparation for conducting LAB 2.

Generally, hit CONTROL & CLICK ON THE LINK to get to the website.

Ø Horses in Cyberspace – http://www.flmnh.ufl.edu/natsci/vertpaleo/fhc/fhc.htm

Ø Pony Express Newsletter – http://www.flmnh.ufl.edu/ponyexpress/pe_newsletters.htm

- How to Identify Fossil Horses http://www.flmnh.ufl.edu/ponyexpress/pony1_1/Pe11.htm
- How to identify Fossil Horses http://www.flmnh.ufl.edu/ponyexpress/pony1_2/Pe12.htm
- **How to Identify Fossil Horses** http://www.flmnh.ufl.edu/ponyexpress/pony1_3/Pe13.htm
- Sex in Fossil Horses & Pseudo Horses http://www.flmnh.ufl.edu/ponyexpress/pony1_4/Pe14.htm
- Geographic Variation in Horses http://www.flmnh.ufl.edu/ponyexpress/pony2_2/Pe22.htm
- **Horse Phylogeny** & **Mammal Tooth Structure** http://www.flmnh.ufl.edu/ponyexpress/pony2_3/Pe23.htm
- How Can Horses Stand for so Long? http://www.flmnh.ufl.edu/ponyexpress/

pony2_4/Pe24.htm

- Fossil Horses and Global Environmental Changes & Horse Anatomy http://www.flmnh.ufl.edu/ponyexpress/pony3_1/pe31.htm

- Fossil Horses and the Great American Interchange & Horse Bones – The Ulna and Radius http://www.flmnh.ufl.edu/ponyexpress/pony3_2/PE32.HTM

- Why Do Zebras Have Stripes? http://www.flmnh.ufl.edu/ponyexpress/PONY4_1/PONY.HTM

- Building a Fossil Pit in Your Schoolyard http://www.flmnh.ufl.edu/ponyexpress/pony6_1/Pe61.htm

- **The Last Decade (more or less) of Equid Paleobiology** http://www.flmnh.ufl.edu/ponyexpress/pony13_2/Pe132.html

The above sites link to the University of Florida's Museum of Natural History. Dr. Bruce MacFadden, perhaps the world's foremost expert in horse fossils, has visited the John Day Fossil Beds many times in the past. He was very glad to see that we are referencing his research information in the National Park Service horse kit.

Ø Here is another site that offers information on horses and other science subjects -
http://www.fofweb.com/Subscription/Science/Science-Detail.asp?SID=1&iPin=A0830

LAB 3: **Making a Horse Family Tree** (Teacher Directions)

OVERVIEW: In this lab the students will be constructing and analyzing a three-dimensional graph depicting horse development over time.

The actual data to be used in this lab is a rough approximation, developed by generalizing current data and interpretations on the horse family tree (specifically representing the branch of the family tree relating to *Miohippus-Parahippus-Merychippus* line … refer to LAB 1 – SHEET 2).

Using a three dimensional model that they build, a key realization to be made by students is the effect that the discovery of each fossil will have upon the overall understanding of the horse family tree. The more evidence collected the better our understanding becomes.

PREREQUISITE: It is suggested that LAB 2 be completed before this lab. The students should have a good idea what probability means in statistics, and that science deals primarily with the probability of events (not absolute certainty or absolute truth).

ODOE STANDARDS: Late in the lab there will be a division between Benchmark 3 (Grade 8) study and CIM/CAM study.

Scientific Inquiry: Use interrelated processes to pose questions and investigate the physical world.

Common Curriculum Goal: Collecting and Presenting Data - Conduct procedures to collect, organize, and display scientific data.

Benchmark 3 (Grade 8) - Collect, organize, and display sufficient data to *support analysis*.

CIM/CAM - Collect, organize, and display sufficient data to *facilitate scientific analysis and interpretation*.

TIME LIMITS: This lab could be conducted over a period of 45 minutes. As the
CIM/CAM students may move through this lab faster than younger students, there are
more questions for them to answer and discuss.

TEACHER PREPARATION BEFORE LAB: The teacher should prepare the following
before this lab begins.

Ø Make a copy of LAB 3 – Student Directions, one per each group, or individual student.

Divide your class into smaller discussion groups, one group to a table. Assign a group leader for each group. The leader will read out loud the lab directions.

- Ø You will need 70 pennies for each group.
- Ø Make a copy of LAB 3 – SHEET 2 (charts) for each group.
- Ø Have a visible clock, and keep time for the students as they work.

START HERE IN CLASS: Team leader, read the following directions out loud, while everyone else in the group reads along silently.

> In this lab your team will be constructing a three-dimensional graph showing horse
> development over time. The graph will represent a part of the horse family tree.
>
> Read the following STEPS carefully, and follow them in order. Do not skip over parts,
> or look ahead. There will be questions in this activity that your group will get to discuss and answer.

Step One: Lay your 70 pennies out on a table. The pennies will be used to produce the three-dimensional graph. Each penny will represent one horse fossil find (with at least one molar tooth) discovered in the John Day Fossil Beds.

Step Two: Take the chart entitled LAB 3 – MASTER CHART and lay it on the table. Note that the figures along the left side represent the age of layers of earth (strata), from 31 million years ago up to 23 million years ago. For example, the 31 will stand for layers of earth 31 million years old.

The numbers along the top represent the horse BL's (body-lengths), in centimeters, determined from each fossil specimen found. Remember your LAB 2 studies where you determined the approximate length of the horse body just from the length of the skull?

Body lengths correlate well to the over-all size, or mass, of a horse. The body length tends to indicate the characteristic of speed – a larger BL is generally faster.

Step Three: Each black dot on the Master Chart represents a hypothetical horse fossil found in the John Day Fossil Beds. Place a single penny over each dot. If there is more than one dot in a square, stack the pennies.

Pennies that are stacked, or stacked next to each other, should be placed carefully so as not to knock over other pennies on the graph. Once you have placed all the pennies, look at your 3-D graph and answer the following.

First Question: Note the group of horse fossils discovered on or next to the 53cm column. Note the group of fossil finds next to the 61cm column.

The fossils of the 61cm horses show different physical characteristics than the group of fossils on or next to the 53cm column on the graph. There is enough difference in physiology (particularly in size and teeth patterns) that the two groups are considered different species of horses by scientists. The 61cm horses have teeth that could have been used for grazing. The 53cm horses have teeth that would have been used for browsing.

Is there enough information on your 3D chart to declare, with high probability, that the younger group evolved from the older group? (yes or no) ____

Why do you think so?

(**brief answer:** The answer to the yes or no question is NO. There is too much of a gap in evidence
on the graph between the fossil finds on the graph representing the two horse groups, 61cm and 53 cm
columns. There is no suggestion from dots/pennies that the one group leans toward the other. One
group did come after the other in time.

High probability [scientific fact] is not certainty, as akin to absolute truth. If we were basing our explanations in this study just upon the fossil finds presented in the graph [as pennies] there would be much room to argue error due to the small number of finds. The 3D chart is suggestive by needs more fossil finds.

Just what does finding a single fossil mean regarding statistics and probability? Consider this. Based upon modern observations of the numbers of life forms and the burial of remains [first step in fossilization], a very liberal estimate of the chances of fossilization for an individual from a population is, say, one-in-a-million. [The odds are probably much greater, and thus fossils are less likely.] If this is so, then finding a few fossil specimens of the same physiology [species] indicates a significant look-alike population once did live. This removes the common argument that varied fossils are just “freak” mutations.

Some argue that since “freak” mutations [significant, abnormal changes in physiology] do occur, a new fossil find may not be a new species but just a gross mutation from the normal population appearance for an individual. OK, playing along with that argument ... so we did find the one-in-a-million freak mutation in the population. If we find two fossil specimens exactly alike, what are the chances of us only finding the two freaks in the population, given a one-in-a-million chance each? Now what are the chances of them being freaks if we find more identical specimens? Also, if they are identical why are they considered “freaks” from the statistical norm?)

Step Four: You are interested in finding out more and you realize the need to find more horse fossils and add that information (evidence) to your graph. You get a grant of several thousand dollars to hire a paleontologist and field research team to go out and collect horse fossils. You also look for more research from others.

You only have them for a short time (one week) so you direct them to look for fossils in the strata from 31 to 26 million years ago. You hope to add to the fossil data of the 53 cm column horse on your chart.

After one week of exhaustive fieldwork, the paleontologist and field team present their horse fossil finds to you. There discoveries are the dots on the chart called “Paleo Team #1 Finds.” For each dot on this sheet, carefully add a penny to the appropriate square on your MASTER CHART on the table, adding to the 3D graph of your previous fossil finds.

YOU ALSO RECEIVE ADDITIONAL SCIENTIFIC RESEARCH FROM OTHERS …

A. Studies of the plant fossils found in the John Day Fossil Beds have shown that the plant environment of the region showed great change during the period from 27 to 23 million years ago. The vast forests that once entirely covered the region receded slowly during this period, giving way to open terrain and grassy environments. By 24 million years ago there were, perhaps, a few groves of forests remaining that dotted the lowland grassland landscape.

B. Research has shown that the teeth patterns on all the horse fossils on or next to the 53cm column remained very much alike over time, and that the teeth of these horses would best be used for shearing, chopping and grinding browsed vegetation (browsing).

C. More research has shown that the teeth patterns on all the horses in or next to the 61 cm column remained alike over time, and that these teeth could easily be used for grinding tough grasses. The 61cm horse teeth are also significantly taller, over-all, than the browsing teeth from the earlier, smaller horse fossils. In some of the later specimens it was noted that a cement-like substance was becoming evident on the teeth, added to the enamel.

Second Question: Again, look at your master chart 3-D penny chart and consider the additional research information you received.

Is there sufficient evidence from the fossil discoveries to declare

with high probability that the horses in the upper right of the chart evolved from the horses on the lower left of the graph? (Yes or no)____

Why do you think so?

(**brief answer:** The best answer for this yes or no question is still NO**.** Again, a key phrase in the
question is what would be considered “high probability.” Is this set at a level of high percentage, such
as 85%, 95%, or 99% for your students? What is the minimum level of high probability they would
accept?

For a scientist, there is still too much of a gap in fossil evidence on the graph in the area of the
25mya/59cm square. The new fossil finds in 26mya row seem to indicate that a portion of the 53cm
horse population was changing in the direction of the 61cm horse. This is only a suggestion, and only
that the 53cm horses are leaning that way. There is nothing suggestive from the 61cm group at this
point. More fossil finds are needed to fill in the gap.)

Step Five: Horse fossil teeth patterns are good indicators of one type of horse being a descendent of another type. Your group decides to study the teeth patterns of your fossil finds more closely to see if changing teeth patterns may indicate a family tree connection between the earlier 53cm horse group and the later 61cm horse group on your penny chart.

Third Question:

If you had to choose one square on the graph and study the patterns of fossil teeth from the horse(s) on that one square, and you are looking for a connection *between* the 53cm horse column and the 61cm horse column, which one square would you choose that may help you the best?

We choose the square at _____million years old and _____cm.

Why did you choose that square as the best square?

(**brief answer:** The best answer may be selecting the two fossil finds in the 26mya/57cm square.

First of all, if the 61cm horses did evolve from 53cm horses there would be a link between the main columns of the two populations. You should then select a point somewhere ***between*** the two main columns, and not directly within the heart of either of the horse groups.

Secondly, if you are going to study the teeth patterns there must be something to study! You would not select a square on the graph that had no fossil specimens to study. You would not select an empty square and hope to find a fossil later, as you may not find any.

Thirdly, given identical fossil preservation condition, two or more fossil specimens are generally going to give you more information than one specimen. More than one fossil specimen will also better establish the paleo-population, countering the mutant/freak argument discussed before. The 26mya/57cm square has two specimens for study, and is logically the best answer, given the information known. It is not the only answer.)

Step Six: Let us say you received enough grant money to bring the paleontologist and field team back for another week. You want them to find more horse fossils that may help you link the two groups of horse in the family tree. Since the field team won't be with you very long, you have to send them to fossil bed locations of just one time period, or row, on your graph.

Fourth Question:

What one strata time period, or row on your penny chart, would you send them to hopefully find fossils for study?

We choose the _____ millions of years row.

Why that row, that strata?

(**brief answer:** The best answer is to choose the 25mya row.

This question offers the chance to go out to some specific strata and find more fossils to help fill in the graph. If we are looking for a way of linking the 53cm horse with the 61cm horses to establish the possibility of the one evolving from the other, we need to fill in the gaps around the square 25mya/59cm square. That means two layers, or time periods on the graph might be your best choice, the 26mya and the 25mya rows.

But which of the two rows is the better choice? The 53cm horse finds in row 26mya already seem to suggest some of these horses were evolving in the direction of the 61cm horses. There is no such indication from the 61cm horse finds, of them evolving from the direction of the 53cm horses. For all we know the 61cm horses evolved from an older horse in the 67cm range, and the 53cm horses died off with no descendants.

Looking for fossils in the 25mya row may yield fossil finds that fill in the gap between the two groups of horses thus establishing a direct connection of evidence.)

Step Seven: Surprise!!! Impressed with your work, the U.S. Government has accepted your grant proposal and given you more money for further horse family tree research. You have been given enough money to have two paleontology field teams prospect out in the John Day Fossil Beds for several months. You initiate this project and after several months the scientific teams present you with their new horse fossil finds.

Look at the Paleo Teams #2 & #3 Finds chart. Carefully add the new fossil discoveries to your MASTER CHART using the pennies.

There seems to be a problem. Even after all the teams have hiked the varied landscape and prospected for fossils throughout the John Day Fossil Beds, there are no fossils found for the 29mya row!

Fifth Question:

What reasons may account for the lack of horse fossils in the 29 million year old row of your master chart graph?

(**brief answer:** There are many possible answers to this question, such as ...

- Ø Pure luck – fossil hunters were not lucky and missed finding any exposed fossils.
- Ø The fossilization process 29mya was poor and no [or very few] fossils developed.
- Ø There are no 29mya layers exposed on the surface today for us to prospect, though they may be down there somewhere.
- Ø The population levels of the species dropped to such a low point 29mya that few if any fossils were formed.
- Ø The species population migrated to a new habitat, out of this area for some reason, so no fossils would be formed here. Later in time they migrated back.

A key point to bring out, as it refutes a common answer given by students, is that there is absolutely NO evidence anywhere that even suggests a plant or animal species can go out of existence and then come back into existence, naturally.

With our current knowledge of genetics and cloning, who knows what humans will be able to do in the next few decades regarding bringing back extinct species, but that is another discussion.

Fossil beds differ around the world. The John Day Fossil Bed fossils are so spread out in eastern Oregon, covering over 10,000 square miles, that just digging anywhere would be fruitless. Our fossil hunters prospect, meaning they walk or crawl across the surface of the land and look for fossils just starting to erode out. Once they find a partially buried fossil and record all the needed information about the burial site, then they start digging to remove it for inclusion in the museum collection and later study.)

Now look again at your 3-D penny chart of horse fossil finds. The stacked pennies are similar to small mountain ridges.

Sixth Question:

Why did the horse fossils that make up the mountain ridge in the 53cm column probably dwindle down to nothing over time?

(**brief answer:** With the current research data, the best answer lies in the condition
of the environment of 53cm horses, which was changing significantly.

Research information presented earlier stated that the landscape was primarily forested up to about 25-20 mya when the changes started to occur. The forests receded significantly, probably caused by a changing climate in this area during the same period of time, evidenced by other studies. In the end, scattered, small patches of forests 24mya may not have been able to support a large enough population to survive other living conditions. The fossils of the main population of 53cm horses showed their structural features did not change near as fast as their surroundings did. An offshoot of their population did showed significant and fast changes, leading to 61cm horse group. The main population struggled on in their own traditional way in the forests, as a small splinter group took off in another direction, toward the grasslands.)

STOP … At this point the CIM/CAM students will head in another direction of study, presented below.

The Benchmark 3 (grade 8) students should all gather together and discuss the following questions presented by the teacher, finishing out LAB 3:

1) Do you think a single horse fossil can affect how we think about the family tree of horses and how they lived?

2) Do you think that more horse fossil finds give you a better picture of the horse family tree?

3) Other than the plants they ate, what other kinds of things would have affected how the horses lived and survived through time, and may have affected the shape of your penny chart.

CIM/CAM students continue here …

Step Eight: You have received additional research information from another source.

YOU OBTAIN ADDITIONAL SCIENTIFIC RESEARCH ...

A. Another fossil study, focusing on cat-like animals that used to live in the John Day Fossil Bed region, has revealed two common types of cats that lived here. Both types have a pair of saber-like teeth at the front of their skulls.

B. One of these types of saber-toothed cat (call it Cat #1) had a bulky body built more for strength rather than speed. It shows up in the fossil record from 31 to 25 million years ago, after which, it seems to have become extinct. It stayed about the same size throughout its existence, large enough to attack and easily bring down the 53cm column horses by itself.

C. The other type of saber-toothed cat (call it Cat #2) first shows up in the fossil record about 27 million years ago, and disappeared about 24 million years ago. This cat showed a gradual increase in size over its brief existence, and before it became extinct, it seemed large enough to be able to bring down a 61cm horse. The skeletons of Cat #2 suggest a slimmer cat than Cat #1. Cat # 2 seemed built for running. .

D. THE FOSSIL RECORD "CAT-GAP MYSTERY": This is a remarkable mystery. Cat-like creatures, Nimravids and Felids, are first seen in the fossil record about 35 million years ago and spread worldwide. The fossil record shows that about 24 million years ago <u>all</u> of the North American cats (Nimravids and Felids) disappeared! They returned to North America from Eurasia about 20 million years ago, after an absence of about four million years. We are still searching for the reasons they disappeared from North America.

Sixth Question: (repeated, as there is new research information)

Why did the horse fossils that make up the mountain ridge in the 53cm column probably dwindle down to nothing over time?

(**brief answer:** The presence of Cat #1 which, based upon its body structure, was not a runner and probably needed forested area to ambush its prey. Cat #1 may have had an increased effect on the horse populations as the size of each forest decreased thus reducing the hiding area for prey. Cat #1 seemed to suffer the same fate as the 53cm horses, due primarily to the change in environment reducing prey numbers. Fossils show that Cat #1 showed stability in body form and did not adapt to the changing environment. An offshoot of the Cat #1 population did, leading to Cat #2.)

Seventh Question:

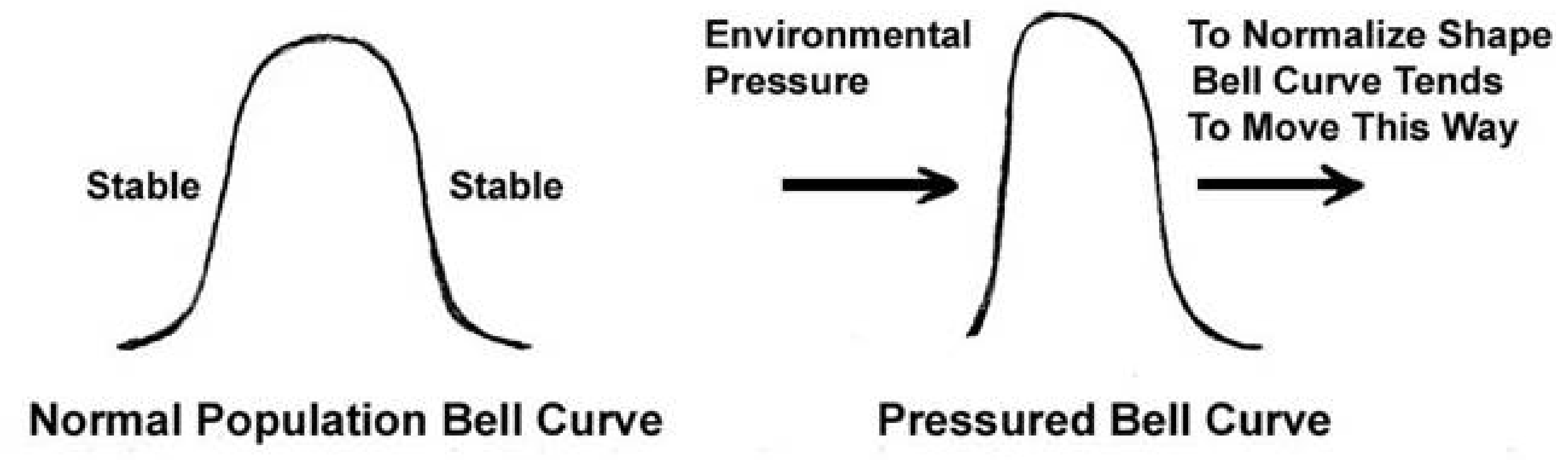
Which of the saber-toothed cats (Cat #1 or Cat #2) probably had the most direct effect on the early and later development of the 61cm horses over time, and how?

(**brief answer:** The best answer is Cat #2, which showed form adaptations that better suited an open, grassy landscape.

Cat #2's size would probably enable it to bring down young/smaller members of the earlier 61cm horses. If they developed paired or pack hunting habits, they possible could bring down adult horses. The advent of open grassy environs within the last 25 million years may have pushed animals such as dogs, cats and hyaenas to adapt a cooperative effort to capture prey, as a single individual in the open would have a harder time than in a wooded area suited for ambush.

The graph illustrates the pressure Cat #2 puts on the early part of the 61cm horse branch, changing the horses' over-all height [which effects over-all speed], AND visa-versa, the horse puts pressure on the cat by the changes. Both show an arms race of increasing speed and size over time, for defensive and offensive reasons.

Look at the horse fossil finds at the 23mya layer and think of the 3D pennies as taking the form of population bell curve.



Now look at the 24mya row of pennies. The peak of the bell curve is at 61cm. The right side, or longer-in-length side, shows a shallower curve with some of the total population. The left side, or shorter-in-length side, shows a very steep slope, suggesting much fewer members of the total population to the left of the bell curve peak. The bell curve would look like something is pushing against the left side of the bell.

Cat #2 may have had a direct effect on the steepness of the left side, pushing the whole bell curve to the right over time. Cat #2 would have been weeding out the smaller, slower members of the horse population. Granted, the number of fossil finds on the graph are minimal. Many more finds are needed to increase our confidence in the bell curve at this point in time - more evidence is desired – more fossil finds.

Note, with the disappearance of Cat #2 about 23mya, the 61cm horses seem to stabilize, the bell curve regaining its normal form. The pressure for the horse to increase speed is gone, and smaller slower horses have a better chance of survival.)

STOP … Congratulations! You have now completed Lab 3.

LAB 3 – SHEET 1: <u>Making a Horse Family Tree</u> (Student Directions)

OVERVIEW: In this lab the students will be constructing and analyzing a three-dimensional graph depicting horse development over time.

The actual data to be used in this lab is a rough approximation, developed by generalizing current data and interpretations on the horse family tree (specifically representing the branch of the family tree relating to *Miohippus-Parahippus-Merychippus* line … refer to LAB 1 – SHEET 2).

> **TIME LIMITS:** This lab could be conducted over a period of 45 minutes. As the
> CIM/CAM students may move through this lab faster than younger students, there are
> more questions for them to answer and discuss.

START HERE IN CLASS: Team leader, read the following directions out loud, while everyone else in the group reads along silently.

> In this lab your team will be constructing a three-dimensional graph showing horse
> development over time. The graph will represent a part of the horse family tree.
>
> Read the following STEPS carefully, and follow them in order. Do not skip over parts,
> or look ahead. There will be questions in this activity that your group will get to
> discuss and answer.

Step One: Lay your 70 pennies out on a table. The pennies will be used to produce the three-dimensional graph. Each penny will represent one horse fossil find (with at least one molar tooth) discovered in the John Day Fossil Beds.

Step Two: Take the chart entitled LAB 3 – MASTER CHART and lay it on the table. Note that the figures along the left side represent the age of layers of earth (strata), from 31 million years ago up to 23 million years ago. For example, the 31 will stand for layers of earth 31 million years old.

The numbers along the top represent the horse BL's (body-lengths), in centimeters, determined from each fossil specimen found. Remember your LAB 2 studies where you determined the approximate length of the horse body just from the length of the skull?

Body lengths correlate well to the over-all size, or mass, of a horse. The body length tends to indicate the characteristic of speed – a larger BL is generally faster.

Step Three: Each black dot on the Master Chart represents a hypothetical horse fossil found in the John Day Fossil Beds. Place a single penny over each dot. If there is more than one dot in a square, stack the pennies.

Pennies that are stacked, or stacked next to each other, should be placed carefully so as not to knock over other pennies on the graph. Once you have placed all the pennies, look at your 3-D graph and answer the following.

First Question: Note the group of horse fossils discovered on or next to the 53cm column. Note the group of fossil finds next to the 61cm column.

The fossils of the 61cm horses show different physical characteristics than the group of fossils on or next to the 53cm column on the graph. There is enough difference in physiology (particularly in size and teeth patterns) that the two groups are considered different species of horses by scientists. The 61cm horses have teeth that could have been used for grazing. The 53cm horses have teeth that would have been used for browsing.

Is there enough information on your 3D chart to declare, with high probability, that the younger group evolved from the older group? (yes or no) ____

Why do you think so?

Step Four: You are interested in finding out more and you realize the need to find more horse fossils and add that information (evidence) to your graph. You get a grant of several thousand dollars to hire a paleontologist and field research team to go out and collect horse fossils. You also look for more research from others.

You only have them for a short time (one week) so you direct them to look for fossils in the strata from 31 to 26 million years ago. You hope to add to the fossil data of the 53 cm column horse on your chart.

After one week of exhaustive fieldwork, the paleontologist and field team present their horse fossil finds to you. There discoveries are the dots on the chart called "Paleo Team #1 Finds." For each dot on this sheet, carefully add a penny to the appropriate square on your MASTER CHART on the table, adding to the 3D graph of your previous fossil finds.

YOU ALSO RECEIVE ADDITIONAL SCIENTIFIC RESEARCH FROM OTHERS …

A. Studies of the plant fossils found in the John Day Fossil Beds have shown that the plant environment of the region showed great change during the period from 27 to 23 million years ago. The vast forests that once entirely covered the region receded slowly during this period, giving way to open terrain and grassy environments. By 24 million years ago there were, perhaps, a few groves of forests remaining that dotted the lowland grassland landscape.

B. Research has shown that the teeth patterns on all the horse fossils on or next to the 53cm column remained very much alike over time, and that the teeth of these horses would best be used for shearing, chopping and grinding browsed vegetation (browsing).

C. More research has shown that the teeth patterns on all the horses in or next to the 61 cm column remained alike over time, and that these teeth could easily be used for grinding tough grasses. The 61cm horse teeth are also significantly taller, over-all, than the browsing teeth from the earlier, smaller horse fossils. In some of the later specimens it was noted that a cement-like substance was becoming evident on the teeth, added to the enamel.

Second Question: Again, look at your master chart 3-D penny chart and consider the additional research information you received.

Is there sufficient evidence from the fossil discoveries to declare with high probability that the horses in the upper right of the chart evolved from the horses on the lower left of the graph? (Yes or no)____

Why do you think so?

Step Five: Horse fossil teeth patterns are good indicators of one type of horse being a descendent of another type. Your group decides to study the teeth patterns of your fossil finds more closely to see if changing teeth patterns may indicate a family tree connection between the earlier 53cm horse group and the later 61cm horse group on your penny chart.

Third Question:

If you had to choose one square on the graph and study the patterns of fossil teeth from the horse(s) on that one square, and you are looking for a connection *between* the 53cm horse column and the 61cm horse column, which one square would you choose that may help you the best?

We choose the square at _____million years old and _____cm.

Why did you choose that square as the best square?

Step Six: Let us say you received enough grant money to bring the paleontologist and field team back for another week. You want them to find more horse fossils that may help you link the two groups of horse in the family tree. Since the field team won't be with you very long, you have to send them to fossil bed locations of just one time period, or row, on your graph.

Fourth Question:

What one strata time period, or row on your penny chart, would you send them to hopefully find fossils for study?

We choose the _____ millions of years row.

Why that row, that strata?

Step Seven: Surprise!!! Impressed with your work, the U.S. Government has accepted your grant proposal and given you more money for further horse family tree research. You have been given enough money to have two paleontology field teams prospect out in the John Day Fossil Beds for several months. You initiate this project and after several months the scientific teams present you with their new horse fossil finds.

Look at the Paleo Teams #2 & #3 Finds chart. Carefully add the new fossil discoveries to your MASTER CHART using the pennies.

There seems to be a problem. Even after all the teams have hiked the varied landscape and prospected for fossils throughout the John Day Fossil Beds, there are no fossils found for the 29mya row!

Fifth Question:

What reasons may account for the lack of horse fossils in the 29 million year old row of your master chart graph?

Now look again at your 3-D penny chart of horse fossil finds. The stacked pennies are similar to small mountain ridges.

Sixth Question:

Why did the horse fossils that make up the mountain ridge in the 53cm column probably dwindle down to nothing over time?

STOP … At this point the CIM/CAM students will head in another direction of study, presented below.

The Benchmark 3 (grade 8) students should all gather together and discuss the following questions presented by the teacher, finishing out LAB 3:

1) Do you think a single horse fossil can affect how we think about the family tree of horses and how they lived?

2) Do you think that more horse fossil finds give you a better picture of the horse family tree?

3) Other than the plants they ate, what other kinds of things would have affected how the horses lived and survived through time, and may have affected the shape of your penny chart.

CIM/CAM students continue here …

Step Eight: You have received additional research information from another source.

YOU OBTAIN ADDITIONAL SCIENTIFIC RESEARCH ...

A. Another fossil study, focusing on cat-like animals that used to live in the John Day Fossil Bed region, has revealed two common types of cats that lived here. Both types have a pair of saber-like teeth at the front of their skulls.

B. One of these types of saber-toothed cat (call it Cat #1) had a bulky body built more for strength rather than speed. It shows up in the fossil record from 31 to 25 million years ago, after which, it seems to have become extinct. It stayed about the same size throughout its existence, large enough to attack and easily bring down the 53cm column horses by itself.

C. The other type of saber-toothed cat (call it Cat #2) first shows up in the fossil record about 27 million years ago, and disappeared about 24 million years ago. This cat showed a gradual increase in size over its brief existence, and before it became extinct, it seemed large enough to be able to bring down a 61cm horse. The skeletons of Cat #2 suggest a slimmer cat than Cat #1. Cat # 2 seemed built for running. .

D. THE FOSSIL RECORD "CAT-GAP MYSTERY": This is a remarkable mystery. Cat-like creatures, Nimravids and Felids, are first seen in the fossil record about 35 million years ago and spread worldwide. The fossil record shows that about 24 million years *ago <u>all</u> of the North American cats (Nimravids and Felids) disappeared! They returned to North America from Eurasia about 20 million years ago, after an absence of about four million years. We are still searching for the reasons they disappeared from North America.*

Sixth Question: (repeated, as there is new research information)

Why did the horse fossils that make up the mountain ridge in the 53cm column probably dwindle down to nothing over time?

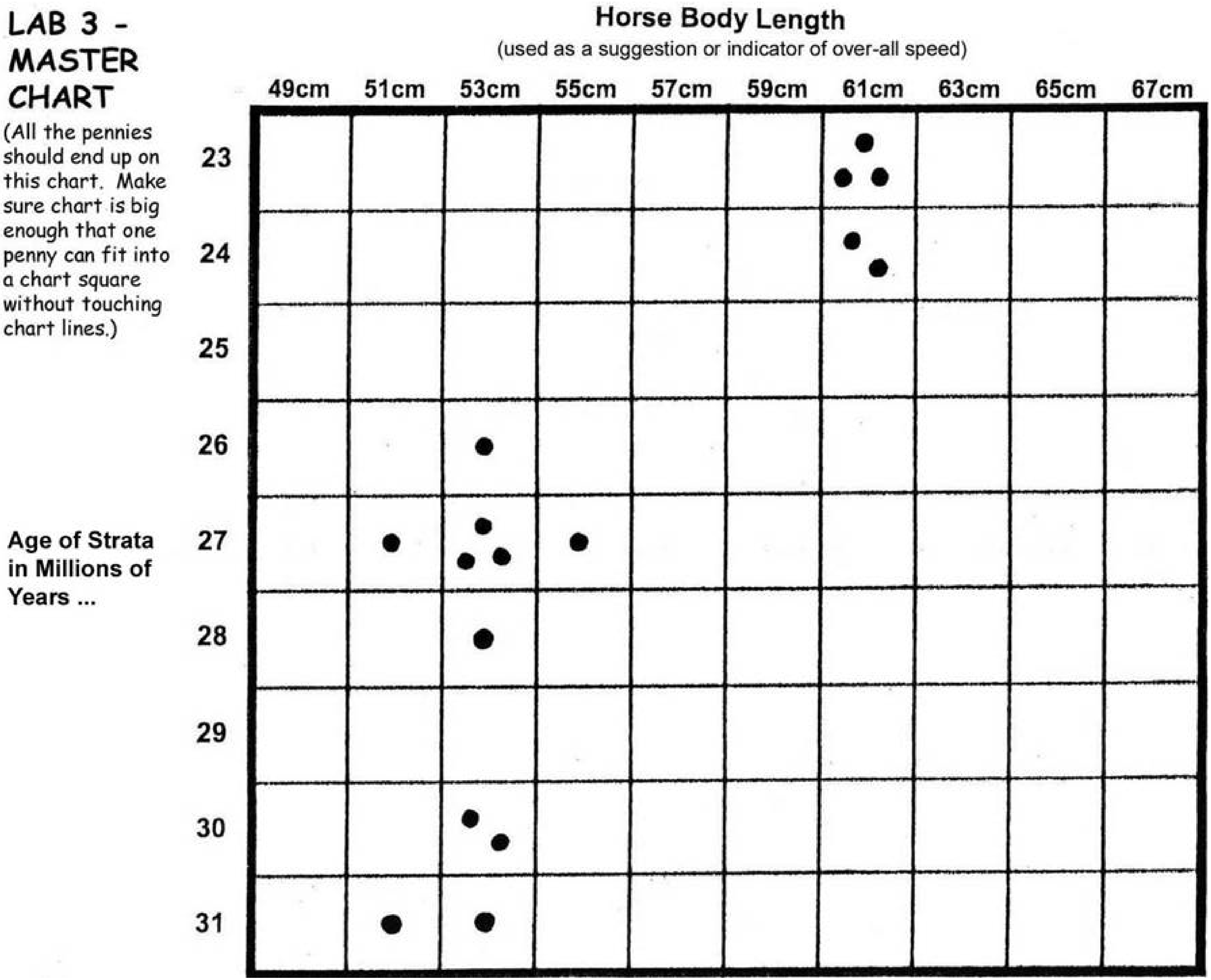
Seventh Question:

Which of the saber-toothed cats (Cat #1 or Cat #2) probably had the most direct effect on the early and later development of the 61cm horses over time, and how?

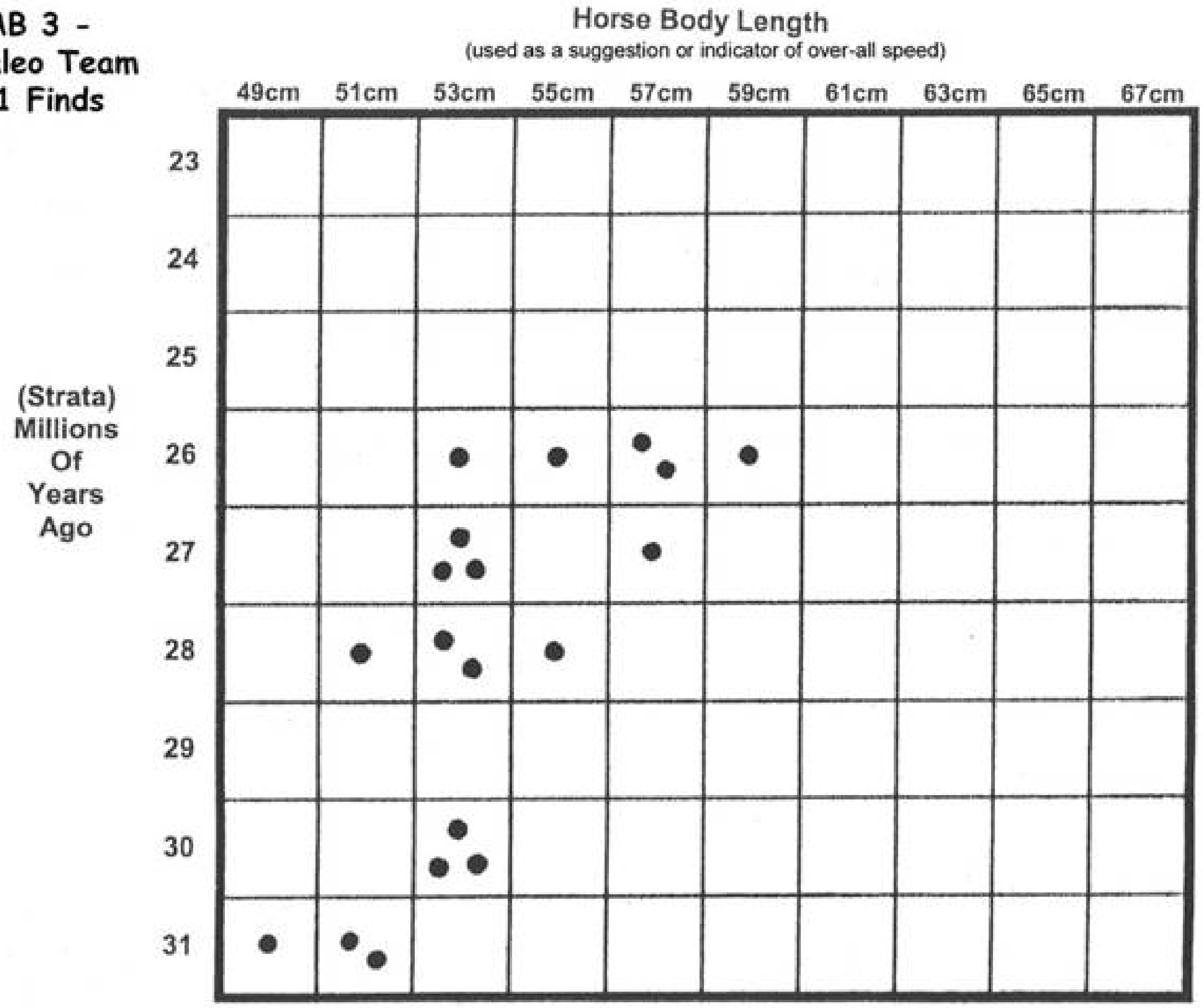
STOP … Congratulations! You have now completed Lab 3.

LAB 3 - MASTER CHART

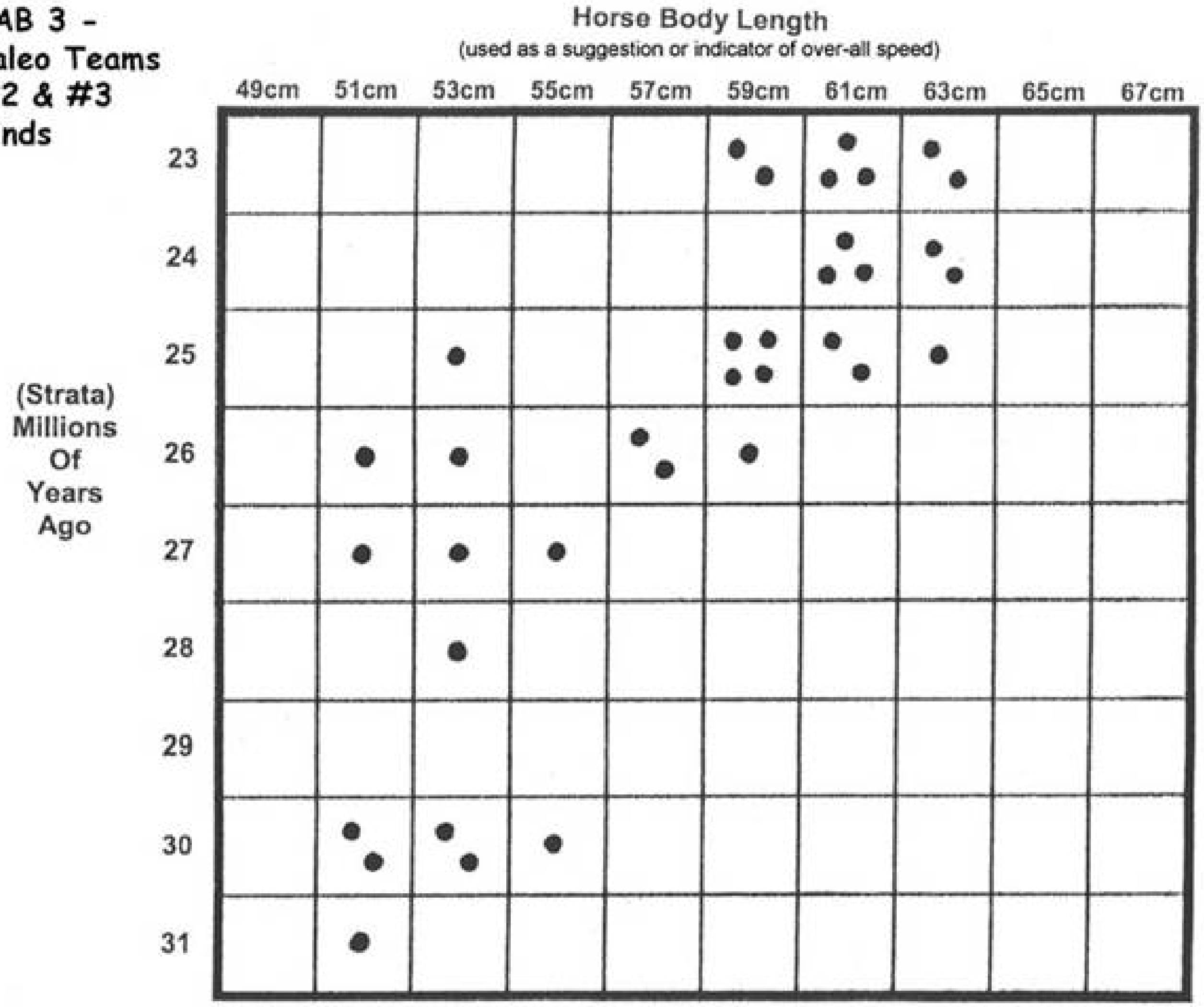
(All the pennies should end up on this chart. Make sure chart is big enough that one penny can fit into a chart square without touching chart lines.)



LAB 3 - Paleo Team #1 Finds



LAB 3 - Paleo Teams #2 & #3 Finds



LAB 3 - TEACHER REFERENCE

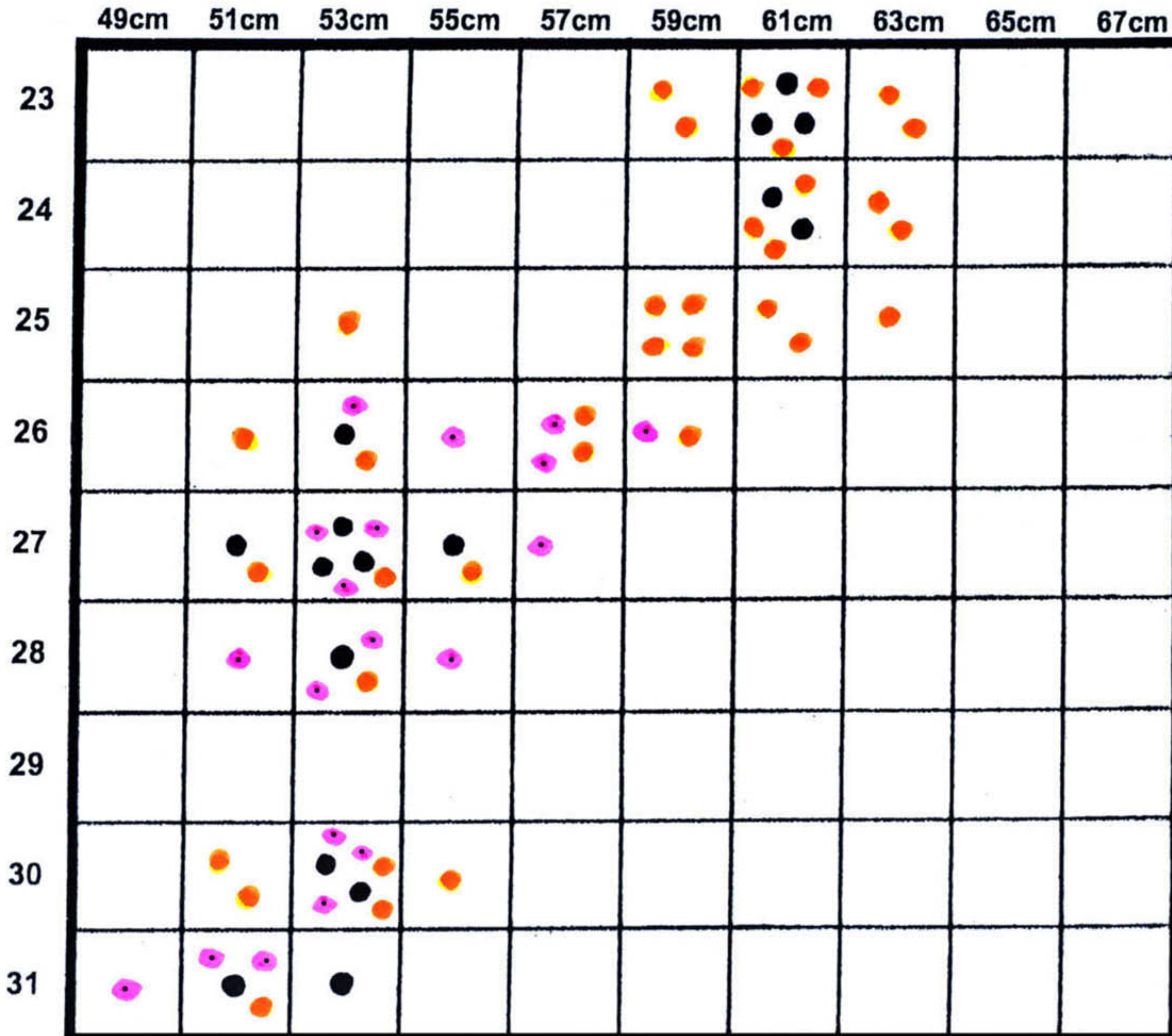
MASTER CHART

(All the pennies should end up on this chart. Make sure chart is big enough that one penny can fit into a chart square without touching chart lines.)

Age of Strata in Millions of Years ...

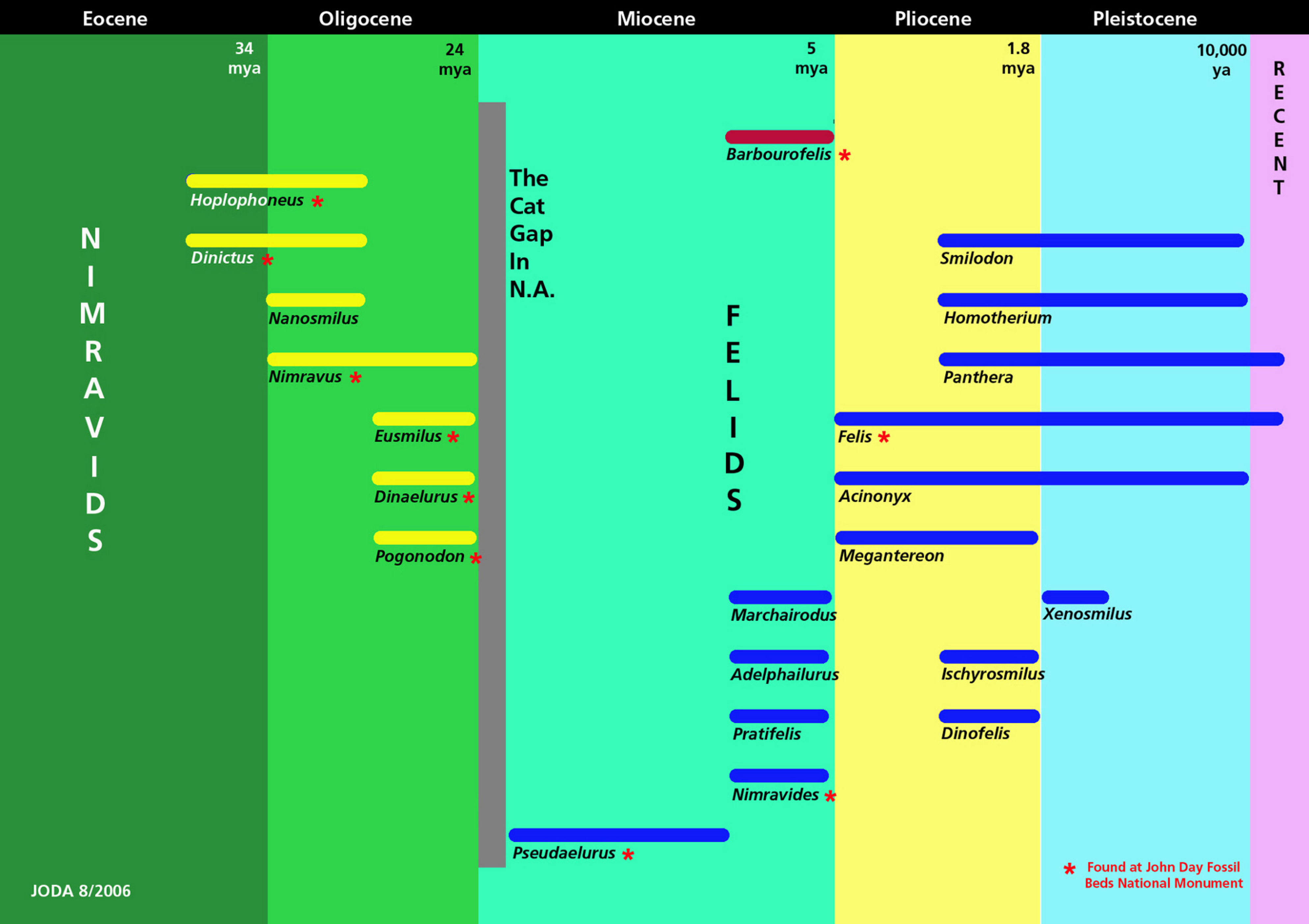
Horse Body Length

(used as a suggestion or indicator of over-all speed)



Black Dots = Original Finds   Pink Dots = Paleo Team #1 Finds   Orange Dots = Paleo Teams #2 & #3 Finds

North American "Cat-Like" Fauna (labeled by genera)



LAB 4: <u>**You Are What You Eat**</u> (Teacher Directions)

OVERVIEW: Horse fossil teeth contain material from the plants the horse ate when it was alive. The study of horse fossil teeth can give us insight into prehistoric plant communities and even a major horse extinction period.

Students will do some pre-class research, using the internet or library, preparing for a teacher-led, classroom discussion either as individuals or in groups.

PREREQUISITE: Student completion of LAB 1 (Introduction to John Day Fossil Beds) & Lab 2 (A Study of Horse Fossils)

ODOE STANDARDS: This activity targets the following science standards. It has been designed for use by 9th through 12th grade students.

Scientific Inquiry: Use interrelated processes to pose questions and investigate the physical world.

Common Curriculum Goal: Collecting and Presenting Data - Conduct procedures to collect, organize, and display scientific data.

CIM/CAM - Collect, organize, and display sufficient data to facilitate scientific analysis and interpretation.

Common Curriculum Goal: Analyzing and Interpreting Results – Analyze scientific information to develop and present conclusions.

CIM/CAM - Summarize and analyze data, evaluating sources of error or bias. Propose explanations that are supported by data and knowledge of scientific terminology.

TIME LIMITS*:* Lab 4 is designed to be conducted over two class periods, each of 45 minutes. There is about one hour total of student research work needed before beginning the two class periods. Student research may be in small groups or done individually. The research is necessary for good class discussion and success.

TEACHER PREPARATION BEFORE CLASSROOM LAB:

The teacher should decide to let the students work as individuals or in small groups. The teacher should also prepare the following. The handouts listed below are available on the enclosed CD.

Make copies of the following LAB 4 sheets:

- Ø SHEET 1 Student Directions (enough for each student, or each group, for classroom discussion)
- Ø SHEET 2 Part A (enough for the other half of the class, for their research period)
- Ø SHEET 2 Part B (enough for the other half of the class, for their research period)
- Ø SHEET 3 (one copy to each student for their research period)**
- Ø SHEET 3 TR (one copy for the teacher as reference)
- Ø SHEET 4 (one copy to each student for their research period)
- Ø SHEET 5 (one copy for each student and teacher, for classroom discussion)**
- Ø SHEET 6 (one, or a few, copies to show students during classroom discussion)
- Ø SHEET 7 (optional, to show students during classroom discussion)
- Ø Previously used LAB 1 – SHEET 2 (horse family tree) would be useful.

** *NOTE: Sheets 3 & 5 are designed to be placed together in the classroom session discussions. Copy them the same size as the original so they will be scaled the same.*

Please become familiar with all the student preparation handouts and review the answers provided in Lab 4. Do review all the LAB 4, teacher reference (TR) sheets on the CD. The TR information will greatly help in your explanations to students.

STUDENT RESEARCH BEFORE CLASSROOM LAB:

To be able to complete Lab 4 successfully students will need to do some research before the discussions in the two classroom sessions. They will also need to have previously participated in Lab 2 in the Horse Fossil Kit, which will help them understand and visualize the types of teeth horses had over time.

In their research time, students will need to:

Ø Take the data from Sheet 4 and add it to Sheet 3. (Familiarity with the data one gathers and works with is important. Adapting data into a usable form is also important. Each student should have their own Sheet 3, one they filled in, to refer to during the classroom session.)

Ø Students should review thoroughly either SHEET 2 Part A or B, whichever one they were given, and complete the "Research Exercise" on the handout. (In class, as part of their research time, students could work 2-3 per computer, researching together.) **Students with Part A should not share handout information with Part B students, and visa-versa. ****

Ø Have students review the LAB 1 – SHEET 2, horse family tree diagram.

Ø (Optional) In their research, have the students sketch the shapes of at least eight different types of grass phytoliths to become familiar with the many shapes. Post their sketches in class for others to see (maybe posting one of each shape?).

**Note: Giving a student both Part A & B may provide so much information that it will lead to easy answers and little thought later in the class discussions. We would like the students to share unknown information later in the class discussions, stimulating thought and the improvement of initial explanations during the discussions.

CLASSROOM DISCUSSIONS*:* Once the students have done their research, conduct the following discussion/study in the classroom over two class periods. Let the students know they are free to share information from their research. Perhaps post the drawings of phytoliths done for the optional activity.

Note to the Teacher: Many questions are provided for you to ask of the students. If you can devise ways for your students to come up with similar questions, leading to their discovery of the answers, it would be a more effective learning experience. Some of the answers provided may be less than satisfying to you and you may need to research some more detailed information. Please feel free to experiment with the following procedures, adding or subtracting to meet the needs of your students.

Remember that there are two sets of clue sheet information, so half of the student group will not have the same knowledge the other half does. This means when a student shares information from the clue sheets they should read the clue sheet reference out loud for all to hear. This will allow many of the students the chance to process new information into their base of knowledge to come up with explanations and answers.

First Day Classroom Discussion …

Step One. (20 minutes) Discuss the four questions in the students' preparation work, to establish a class wide foundation of knowledge. Ask if there was any misunderstanding of the information on the clue sheets, and briefly clear these up, or defer to later discussion.

Step Two. (5 minutes) Review STUDY PACKAGE 4 – SHEET 3, the chart filled in by the students, and have them compare their results to make sure the charts are accurate and display the same data. You may wish to post a larger version of the filled-in chart for students to compare theirs to. Ask the students if there is anything unusual about the chart configuration that they have questions about, and briefly clear these up, or defer to later discussion.

Step Three. (15 minutes) Regarding Sheet 3, ask these questions of the Students in Class and discuss the answers.

a. Does the Sheet 3 graph suggest when grasses first made an appearance In North America?

[brief answer: The clue sheet indicated that grasses first swept through North America about 20-25 million years ago. Before that there were no grasses in North America, and no grazers, just browsers as herbivores. Sheet 3 seems to indicate that about 18 million years ago we see species of what we will call the first grazers, of the genus *Merychippus*, with mesodont teeth rather than brachydont teeth.]

b. How was the line between hypsodont and very hypsodont selected?

[brief answer: We have in the world today seven species of horses (all the genus *Equus*) with very long teeth. Modern horse teeth, the survivors over time, have been selected as the standard for “very hypsodont.” The shortest of the modern teeth was selected to become the minimum length used to describe “very hypsodont” teeth. Of course, other lengths could have been selected as the dividing lines between the types of teeth. The minimum length for mesodont teeth was selected by using the measurements from fossil teeth of the first “grazing” horse. Without fossils we would not even realize the great degree to which horse teeth have changed over time. Even without fossils, one would have to wonder what went on if they compared horse teeth to other mammal teeth like those of humans.]

c. If each bit of data represents one horse species, does Sheet 3 tell you the total number of different horse species?

[brief answer: No. There may be some horse fossils of different species yet to be discovered, or if they were discovered they may have been mis-identified, or they may have been left out of the given data because the discovery has not yet been published for scientists worldwide to review. With over 140 years of horse fossil discoveries and millions of horse fossils found worldwide, the data on fossil horse species is fairly complete, with new species coming to light rarely.

Even if Sheet 3 showed all the species that ever lived between 18 and 1 million years ago, many of the species lived longer than one million years and are counted on more than one row. A quick look at the <u>Phylogeny of the Equidae</u> diagram, LAB 1 – SHEET 2, may help. Remember, the names on that diagram are genus level names, not down to species level.]

d. Of the three groups of data, mesodont, hypsodont, and very hypsodont, which group shows the most severe loss of species in a one million year period?

[brief answer: There are three possible rows on Sheet 3 that indicate a significant drop in horse species; the 14-13 mya row, the 7-6 mya row, and the 5-4 mya row.

The 14-13 mya row seems to be part of gradual decline in species over three million years; the entire mesodont data almost taking the shape of a bell curve on its side.

The 7-6 and the 5-4 mya rows show severe drops in a million year period. Of the two, the 7-6 drop is most severe, and will be the subject of study in class.

Should someone ask why the severe drop in off in "very hypsodont" horses at the 5-4 mya rows, followed by a comeback in the last three million years, there is a likely answer that relates to plate tectonics. About 4-3 million years ago, a moving South American Plate connected to the North American Plate forming the Central America-Panama land bridge. Creatures from South America spread into North America, and vice-versa – "The Great American Interchange." This exotic species mixing must have been very competitive and stressful to all creatures on both continents, affecting population levels and causing some extinctions. This may be the primary reason for the drop in horse species at 5-4 mya. A look at the Phylogeny of the Equidae diagram, LAB 1 – SHEET 2, will show the spread of horses into South America. See also LAB 2 – TR regarding the Pony Express Newsletter article The Great American Interchange.]

Step Four. (5 minutes) Hand out a copy of LAB 4 – SHEET 5 to each of the students for a quick review, to be used in the next class session. Point out the graph's vertical axis for millions of years and the horizontal for the amount of C13 isotopes.

Questions to ask the students.

e. What is the source for the C13 isotope readings, fossil grasses or fossil horse teeth?

[brief answer: As the title of Sheet 5 indicates, material from horse teeth are measured to get the readings. It may baffle some students that we used material from an animal, and not the material from the plant in question, to get information about the plant. Then using what we learned about the plant we then turn around and explain what may have happened to the animal, the original source. You may wish to discuss the validity in this later. Refer to the Pony Express article on Fossil Horses and Global Climate Changes in the LAB 2 – TR.]

f. How did we get the isotope readings in the laboratory?

[brief answer: To analyze the carbon content of fossil mammals, a small sample of enamel (about 3/16 inch) is cut from the fossil tooth, powdered, and cleaned. It is then mixed with acid causing a reaction to release CO2 gas containing the carbon. The gas is purified and collected in glass sample tubes. The glass tubes are placed in a mass spectrometer and cracked to release the gas to be analyzed. The different proportions of carbon isotopes can be detected. C12 and C13 isotopes are of primary interest.]

g. Why don't we just measure the amount of C4 in a fossil horse tooth?

[brief answer: There are no C4 (or C3) compounds in the teeth. The C4 plants photosynthesize carbon into 4-chained compounds when making plant tissue. When the horse came along and ate the plant these compounds were digested, broken down, and processed into horse tissue. The carbon was passed on into all of the horse tissues, which included carbon isotopes, mixed in a homogeneous way throughout the horse tissue.]

h. Why can isotope C13 be used to indicate C4?

[brief answer: When a C4 plant photosynthesizes carbon into a 4-chained compound it strongly favors using C13 isotopes over other carbon isotopes. A C3 plant will favor C12 isotopes in constructing 3-chained compounds. A higher concentration of C13 in the tissue of a grazing animal over C12 indicates that the animal has been eating more mass of C4 grasses than C3 grasses, which also indicates what types of grasses that were available to eat.

We are looking for the detailed explanation as to why C13 is better for 4-chained compounds than C12. The answer is out there in some study. When we find it we will add that explanation here.]

Second Day Classroom Discussion ...

Step Five. (15 minutes) Look over SHEET 5 and review the information covered in the last five minutes of the last session. Clear up any miss-understandings.

Questions for the Students:

i. Does Sheet 5 indicate that C3 plants have become extinct with the rise of C4 plants?

[brief answer: Sheet 3 does not address data on C3 plants in any way. It does suggest that there was a change in the number of C4 grasses available to eat, perhaps to the detriment of C3 grasses, but it does not suggest C3 grasses became extinct.]

j. Does a significant increase 7 to 6 million years ago in the C4 indicator (C13 isotope) in horse teeth suggest to us anything about what horses were eating when they were alive, what was available to eat, or eating habits?

[brief answer: The behavior of grazing horses today may reflect the behavior of horses in the past – *the present is the key to the past*. To a horse in a herd grazing across the plain, one grass may be the same as another. Any choice made by the horse is probably based on taste and immediate availability. Perhaps the herd leader knows where the “greener pastures” are located and directs the herd there when possible.

Even though the mantra of life for a wild horse is *eat-survive-reproduce*, it is not at all likely that a horse would realize that one type of grass may wear more on the teeth over time and thus would be detrimental to survival, then decide to eat the less damaging grass instead and pass the information on to the population of horses. They would generally eat the grasses that were in front of them.

Not being able to test the taste (palatability) of the varied grasses over time (look at the broad diversity of grass species today), the interpretation of the Sheet 5 C13 isotope proportions assumes that *availability* is reflected by the figures. If the C3 and C4 grasses are mixed in a certain proportion across a plain at a specific point in time, horses will eat the grasses in pretty much the same proportions, and these proportions will be reflected by the homogeneous mix of isotopes in the tissue of the horse body.

The Sheet 5, 7-6 mya row does strongly suggest that there was a great change, over much of North America in a short period of time, in the number of C4 grasses *available* to eat, and that the grasses were eaten. We know they were eaten as the evidence for the C4 plants was found in the eaters.]

Step Six. (10 minutes) Have the students take both SHEET 3 and SHEET 5 out and place them on their desks. SHEET 5 should be on the left. Have them line up the arrows on both charts, such that the rows of millions of years on the vertical axis on both charts line up with each other horizontally.

k. By combining both these charts, what can we possibly learn about the major extinction of hypsodont horses between 7 and 6 million years ago?

Open this up for group discussion, and ask for research information to support their explanations. Have SHEET 6 (C3 & C4 Grass Phytoliths) ready as an example to show the students the difference in phytolith numbers found in C3 grasses compared to C4 grasses.

[brief answer: Combining the two charts gives us more complete visual information to work with. The answer to the above question is based upon comparing the 7-6 mya rows on both charts, where the arrows line up.

Grazing horses with mesodont teeth did not exist in North America during this great change in C4 grass types 7-6 mya. Grazing horses with hypsodont teeth of varying lengths did.

C4 grasses have about three times the amount of phytoliths in their structure. Eating a C4 grass would cause wear on the teeth about three times greater than eating C3 grass. This is a significant amount of wear and, in a population of horses with hypsodont teeth of varied lengths, could lead to early death, lower reproduction rates, and eventual extinction of horse groups over the centuries. This is especially true for those horses with shorter rather than longer hypsodont teeth.

Note the exception on Sheet 3. The fossil species of hypsodont horses after 7 mya were found in the wet and tropical Gulf Coast region, a haven for C3 grasses.

At one time, say 8 mya, we would classify high crowned toothed horses as just hypsodont toothed. There was no need for the “very hypsodont” category. Then 7-6 mya the increase in C4 grasses reduced the number of species of all hypsodont toothed horses. The hypsodont toothed horses that survive this extinction period needed to have teeth that were longer than a certain length to live on a mixture of grasses with higher concentrations of C4 grass. These surviving horses we now call “very hypsodont.” Very hip horses!]

Step Seven. (15 minutes) Students should have the opportunity to discuss the Lab 4 activity they conducted, particularly evaluating sources of error or bias. Please read the following three paragraphs to the students, leading into the questions for discussion.

Physicist Richard Feynman once stated, “What is science? The word is usually used to mean one of three things, or a mixture of them … Science means, sometimes, a special method of finding things out. Sometimes it means the body of knowledge arising from the things found out. It may also mean the new things you can do when you have found something out, or the actual doing of new things. This last field is usually called technology.”

As you may have thought while doing Lab 4, in science the recording and gathering of data rarely comes up with perfectly accurate or all encompassing information that gives us what we might call the “absolute, inerrant truth” about a given study subject. There are always variables, especially true for studies of events that occurred in the distant past. Scientists, in any field of science, need to expect and understand the variables and minimize those variables as much as possible to get the most accurate data they can.

Scientific information deals with probabilities, and when a scientist states a “scientific fact” about something it doesn’t mean that fact is the absolute, inerrant truth, but more like, the fact is probably close to the actual truth. How close, how probable, depends on the amount of variables in the research leading to the discovery of the scientific fact. If there are too many variables, or a variable has a significant margin of error, the scientist might say that the scientific information “suggests, strongly suggests, leads us to believe,” or any such words that indicate that we are approaching the actual truth, but we are not yet close enough to say it is a scientific fact. The scientific process allows us to approach the reality of a natural event in our world far better than any other process.

l. If you know that the scientific testing and data that led you to some new science discovery had a margin of error of 30%, what words would you use to tell to the general public that you think your scientific information is 70% correct? How about 90% correct? How about 98% correct? To you, when does it become a “scientific fact” in your announcement to the public?

m. From your study of Sheets 3 and 5, discuss what you think are the sources of error or bias that may have caused variables in the information presented?

Step Eight. (5 minutes) Question for the students:

n. Is there any aspect of the research and information you covered in

Lab 4 that is so curious to you that you would like to do some further exploration about it?

STOP … Congratulations! You have just completed Lab 4.

LAB 4 – SHEET 1: <u>You Are What You Eat</u> (Student Directions)

OVERVIEW: Horse fossil teeth contain material from the plants the horse ate when it was alive. The study of horse fossil teeth can give us insight into prehistoric plant communities and even a major horse extinction period.

Students will do some pre-class research, using the internet or library, preparing for a teacher-led, classroom discussion either as individuals or in groups.

TIME LIMITS*:* Lab 4 is designed to be conducted over two class periods, each of 45 minutes. There is about one hour total of student research work needed before beginning the two class periods. Student research may be in small groups or done individually. The research is necessary for good class discussion and success.

STUDENT RESEARCH BEFORE CLASSROOM LAB:

To be able to complete Lab 4 successfully students will need to do some research before the discussions in the two classroom sessions. They will also need to have previously participated in Lab 2 in the Horse Fossil Kit, which will help them understand and visualize the types of teeth horses had over time.

In their research time, students will need to:

Ø Take the data from Sheet 4 and add it to Sheet 3. (Familiarity with the data one gathers and works with is important. Adapting data into a usable form is also important. Each student should have their own Sheet 3, one they filled in, to refer to during the classroom session.)

Ø Students should review thoroughly either SHEET 2 Part A or B, whichever one they were given, and complete the "Research Exercise" on the handout. (In class, as part of their research time, students could work 2-3 per computer, researching together.) **Students with Part A should not share handout information with Part B students, and visa-versa. ****

Ø Have students review the LAB 1 – SHEET 2, horse family tree diagram.

Ø (Optional) In their research, have the students sketch the shapes of at least eight different types of grass phytoliths to become familiar with the many shapes. Post their sketches in class for others to see (maybe posting one of each shape?).

CLASSROOM DISCUSSIONS*:* Once the students have done their research, conduct the following discussion/study in the classroom over two class periods. Let the students know they are free to share information from their research. Perhaps post the drawings of phytoliths done for the optional activity.

Remember that there are two sets of clue sheet information, so half of the student group will not have the same knowledge the other half does. This means when a student shares information from the clue sheets they should read the clue sheet reference out loud for all to hear. This will allow many of the students the chance to process new information into their base of knowledge to come up with explanations and answers.

First Day Classroom Discussion … Teacher Led

Step One. (20 minutes) Discuss the four questions in the students' preparation work, to establish a class wide foundation of knowledge. Ask if there was any misunderstanding of the information on the clue sheets, and briefly clear these up, or defer to later discussion.

Step Two. (5 minutes) Review STUDY PACKAGE 4 – SHEET 3, the chart filled in by the students, and have them compare their results to make sure the charts are accurate and display the same data. Ask the students if there is anything unusual about the chart configuration that they have questions about, and briefly clear these up, or defer to later discussion.

Step Three. (15 minutes) Regarding Sheet 3, ask these questions of the Students in Class and discuss the answers.

a. Does the Sheet 3 graph suggest when grasses first made an appearance In North America?

b. How was the line between hypsodont and very hypsodont selected?

c. If each bit of data represents one horse species, does Sheet 3 tell you the total number of different horse species?

d. Of the three groups of data, mesodont, hypsodont, and very hypsodont, which group shows the most severe loss of species in a one million year period?

Step Four. (5 minutes) Hand out a copy of LAB 4 – SHEET 5 to each of the students for a quick review, to be used in the next class session. Point out the graph's vertical axis for millions of years and the horizontal for the amount of C13 isotopes.

e. What is the source for the C13 isotope readings, fossil grasses or fossil horse teeth?

f. How did we get the isotope readings in the laboratory?

g. Why don't we just measure the amount of C4 in a fossil horse tooth?

h. Why can isotope C13 be used to indicate C4?

Second Day Classroom Discussion … Teacher Led

Step Five. (15 minutes) Look over SHEET 5 and review the information covered in the last five minutes of the last session. Clear up any miss-understandings.

i. Does Sheet 5 indicate that C3 plants have become extinct with the rise of C4 plants?

j. Does a significant increase 7 to 6 million years ago in the C4 indicator (C13 isotope) in horse teeth suggest to us anything about what horses were eating when they were alive, what was available to eat, or eating habits?

Step Six. (10 minutes) Have the students take both SHEET 3 and SHEET 5 out and place them on their desks. SHEET 5 should be on the left. Have them line up the arrows on both charts, such that the rows of millions of years on the vertical axis on both charts line up with each other horizontally.

k. By combining both these charts, what can we possibly learn about the major extinction of hypsodont horses between 7 and 6 million years ago?

Step Seven. (15 minutes) Students should have the opportunity to discuss the Lab 4 activity they conducted, particularly evaluating sources of error or bias. Please read the following three paragraphs with the students, leading into the questions for discussion.

Physicist Richard Feynman once stated, "What is science? The word is usually used to mean one of three things, or a mixture of them … Science means, sometimes, a special method of finding things out. Sometimes it means the body of knowledge arising from the things found out. It may also mean the new things you can do when you have found something out, or the actual doing of new things. This last field is usually called technology."

As you may have thought while doing Lab 4, in science the recording and gathering of data rarely comes up with perfectly accurate or all encompassing information that gives us what we might call the "absolute, inerrant truth" about a given study subject. There are always variables, especially true for studies of events that occurred in the distant past. Scientists, in any field of science, need to expect and understand the variables and minimize those variables as much as possible to get the most accurate data they can.

Scientific information deals with probabilities, and when a scientist states a "scientific fact" about something it doesn't mean that fact is the absolute, inerrant truth, but more like, the fact is probably close to the actual truth. How close, how probable, depends on the amount of variables in the research leading to the discovery of the scientific fact. If there are too many variables, or a variable has a significant margin of error, the scientist might say that the scientific information "suggests, strongly suggests, leads us to believe," or any such words that indicate that we are approaching the actual truth, but we are not yet close enough to say it is a scientific fact. The scientific process allows us to approach the reality of a natural event in our world far better than any other process.

I. If you know that the scientific testing and data that led you to some new science discovery had a margin of error of 30%, what words would you use to tell to the general public that you think your scientific information is 70%

correct? How about 90% correct? How about 98% correct? To you, when does it become a "scientific fact" in your announcement to the public?

m. From your study of Sheets 3 and 5, discuss what you think are the sources of error or bias that may have caused variables in the information presented?

Step Eight. (5 minutes) Question for the students:

n. Is there any aspect of the research and information you covered in Lab 4 that is so curious to you that you would like to do some further exploration about it?

STOP … Congratulations! You have just completed Lab 4.

LAB 4 – SHEET 2 … Part A

CLUE SHEET: The following bits of information, clues, are supported by evidence in the fossil record and/or the present day world. Treat the following information as knowledge passed on from other researchers, to be used in your classroom discussions and problem solving.

1) Horses over time have been classified as either browsers or grazers. There are no browsing horses living today. The general structure and shape of browsing and grazing teeth differ, as the primary plant food differed for each. Grazing horses in the fossil record typically had either mesodont or hypsodont teeth. Merychippus (genus) is the first horse to be considered a grazer, and it was selected because it was the first horse to have cementum as part of its tooth structure, as evidenced in the fossil record. All later grazing horses had this cementum, as do the modern horses.

2) Grasses are a difficult plant to eat and digest, as they are low plants that may gather on the outside dirt and dust kicked up from the ground, and they also contain tiny silica bodies in the cellular structure called phytoliths. The silica on and in grasses is the primary agent for tooth wear in grazing herbivores.

3) Unlike humans, when a horse's teeth wear out they do not eat soup. They starve to death. If their teeth wear out too soon they may fail to produce enough offspring to perpetuate the species, or may not reach adulthood at all if the wear is severe.

4) Early grasses that spread worldwide in the last 40 million years where primarily C3 grasses. The rise of C4 grasses would occur later.

5) The fossil record shows that grasses first made their appearance in South America about 35 million years ago. The first appearance of grasses into North America was about 25-20 million years ago, generally spreading across the continent from south to north.

6) At this point in time scientists are not sure why but C3 grasses tend to gather C12 isotopes (very stable) in their photosynthesis process to produce plant structure, and C4 grasses tend to gather more of the C13 isotopes (less stable). (The unstable C14 isotope is what is measured when using radiometric carbon dating of organic material.)

7) Carbon is a basic building block of the structure of organisms, which includes a variety of carbon isotopes. One organism consuming another makes use of the carbon (isotopes) consumed to build body parts. Horses incorporate the carbon they eat into their bodies in the same proportions as were in the plant food.

8) All the horse mesodont and hypsodont teeth have cementum in their makeup.

Research Exercise: Research the following questions on the internet, or college level science books. We suggest using the Google search engine and type in the key words in **bold** to gather information.

1. What is a phytolith? **(phytolith gallery)**
2. In the photosynthesis process of a plant what is the key difference between a C3 plant and a C4 plant, regarding processing carbon? **(C3 plants C4 plants)**
3. What is an isotope? **(NASA Learning Center isotope)**
4. What is a mass spectrometer? **(mass spectrometer)**

LAB 4 – SHEET 2 … Part B

CLUE SHEET: The following bits of information, clues, are supported by evidence in the fossil record and/or the present day world. Treat the following information as knowledge passed on from other researchers, to be used in your classroom discussions and problem solving.

1) Petrified fossils are primarily formed from the hardest parts of the body, the bones and teeth. Bones are porous and can be saturated with liquid. Teeth are much harder than bone, in reality a kind of rock, and resist saturation over time. Literally, if you have teeth, you have rocks in your head.

2) Buried bones, the first step in the fossilization process, are porous and can become saturated with mineral laden ground waters contaminating the fossil and modifying the carbon content of the bone.

3) In most cases, a petrified fossil of a horse skull has not changed 100% into rock. Generally there is still some of the original organic material left from the living horse, and this material has carbon isotopes in it. The original organic material that is left is primarily found in the teeth.

4) Modern horse teeth are made of four groups of tissue, pulp, dentine, enamel, and cementum. Human teeth do not have cementum.

5) Soft plant leaves, such as grasses, do not become petrified fossils. Leaf fossils are usually found as mold and/or casts, with all of the original organic material gone. Plant wood is hard enough to become a petrified fossil.

6) Generally, C4 grasses contain about three times the amount of phytoliths that C3 grasses contain.

7) One can take a modern tooth, cut a small sample from the enamel, grind the sample up and then add acid to liberate carbon in the form of CO2 gas. The gas can be studied by a mass spectrometer to determine the various elements and isotopes in the gas and the proportion of each.

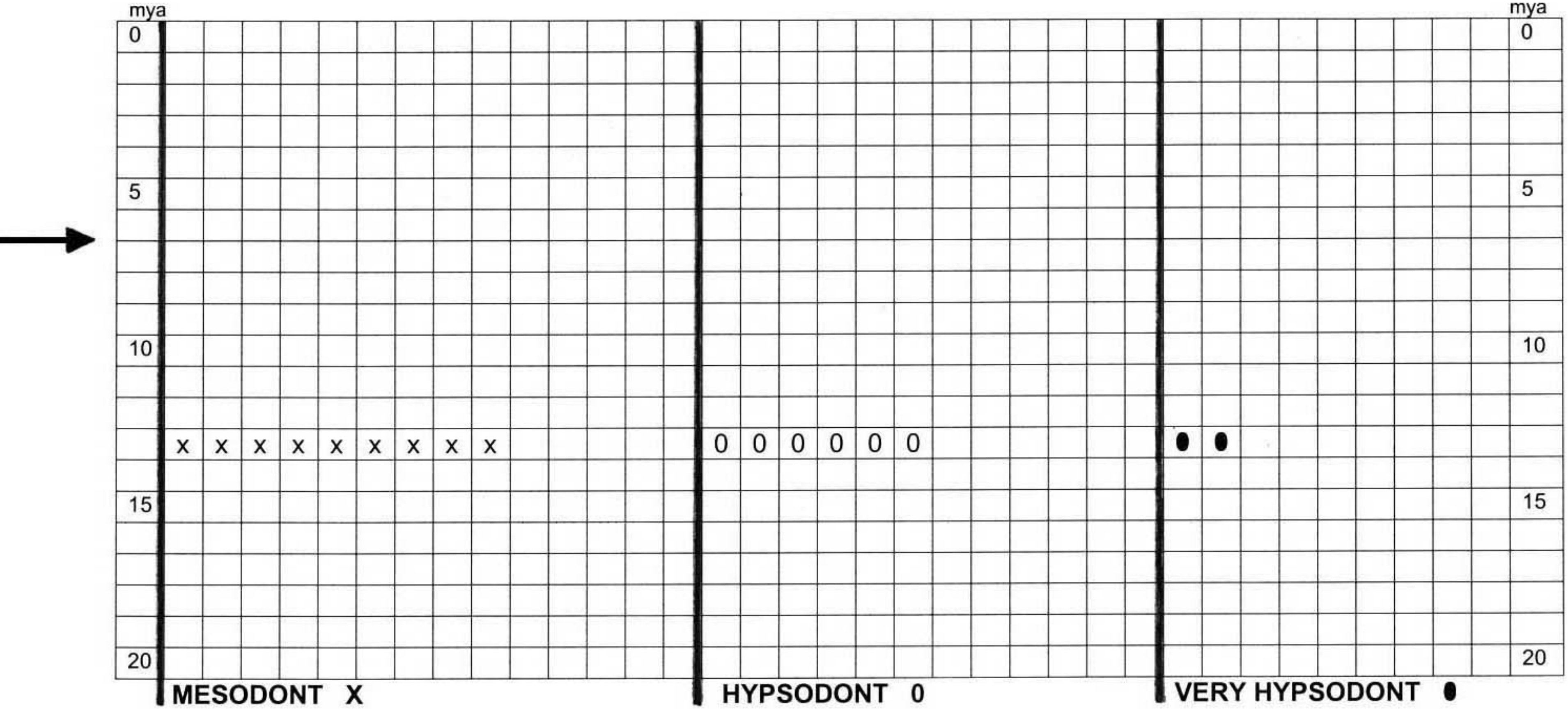
8) A row of phytoliths running lengthwise in a grass blade may look like the row of bones in a backbone. It acts much in the same way as a backbone, giving support to the blade of grass so it does not flop over. It also gives some flexibility, so the blade can bend over and flex back upright. The silica nature of phytoliths also means that the grass is harder to digest and causes wear on teeth, causing some plant-eaters to avoid grasses.

RESEARCH EXERCISE: Research the following questions on the internet, or college level science books. We suggest using the Google search engine and type in the key words in **bold** to gather information.

1. What is a phytolith? **(phytolith gallery)**
2. In the photosynthesis process of a plant what is the key difference between a C3 plant and a C4 plant, regarding processing carbon? **(C3 plants C4 plants)**
3. What is an isotope? **(NASA Learning Center isotope)**
4. What is a mass spectrometer? **(mass spectrometer)**

LAB 4 - SHEET 3

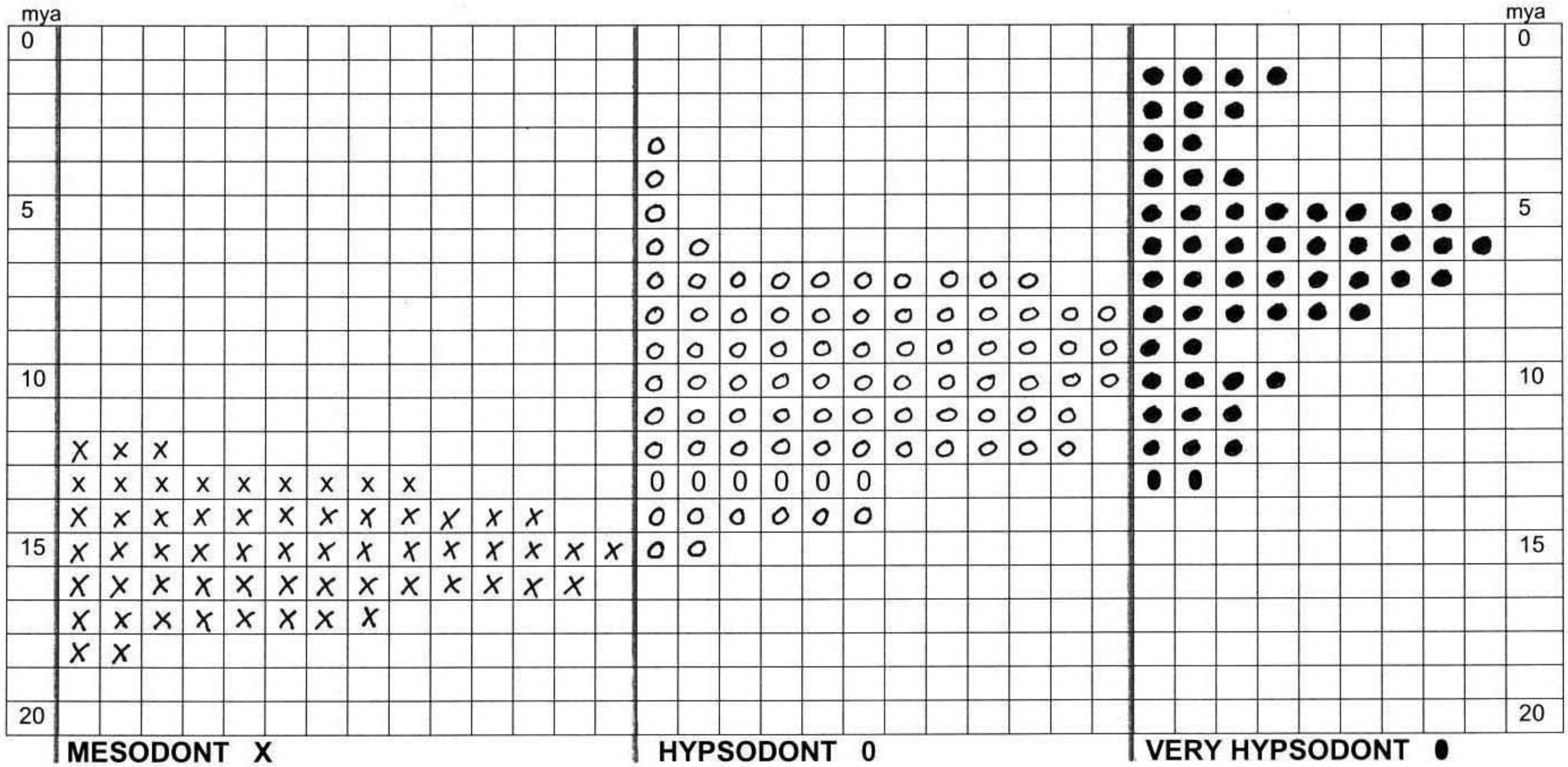
Molar Length for North American Horse Fossils



- each filled block represents one fossil horse species found with a certain tooth height
- mya = millions of years ago
- hypsodont = having long teeth, high crowned
- mesodont = having teeth of moderate length, middle crowned
- brachydont = having short teeth, low crowned
- the minimum "very hypsodont" tooth length is based upon surviving modern horse species, considered to have *very* long teeth compared to earlier horses in the fossil record

LAB 4 - SHEET 3 Teacher Reference

Molar Length for North American Horse Fossils



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- the minimum "very hypsodont" tooth length is based upon surviving modern horse species, considered to have *very* long teeth compared to earlier horses in the fossil record

LAB 4 – SHEET 4

Species Data by Molar Length for North American Horse Fossils

(data to be added to LAB 4 – SHEET 3)

mya	meso	hypso	v hypso
18	2	0	0
17	8	0	0
16	13	0	0
15	14	2	0
14	12	6	0
13	*9**	*6**	*2**
12	3	11	3
11	0	11	3
10	0	12	4
9	0	12	2
8	0	12	6
7	0	10	8
6	0	2	9
5	0	1	8
4	0	1	3
3	0	1	2
2	0	0	3
1	0	0	4

* data already listed on SHEET 3 chart, do not list again

- Ø numbers under the three right columns are the number of species of fossil horses found in the fossil record, with measurable teeth
- Ø mya = millions of years ago, age of strata fossils found within
- Ø meso = mesodont, or middle crowned, teeth of moderate length

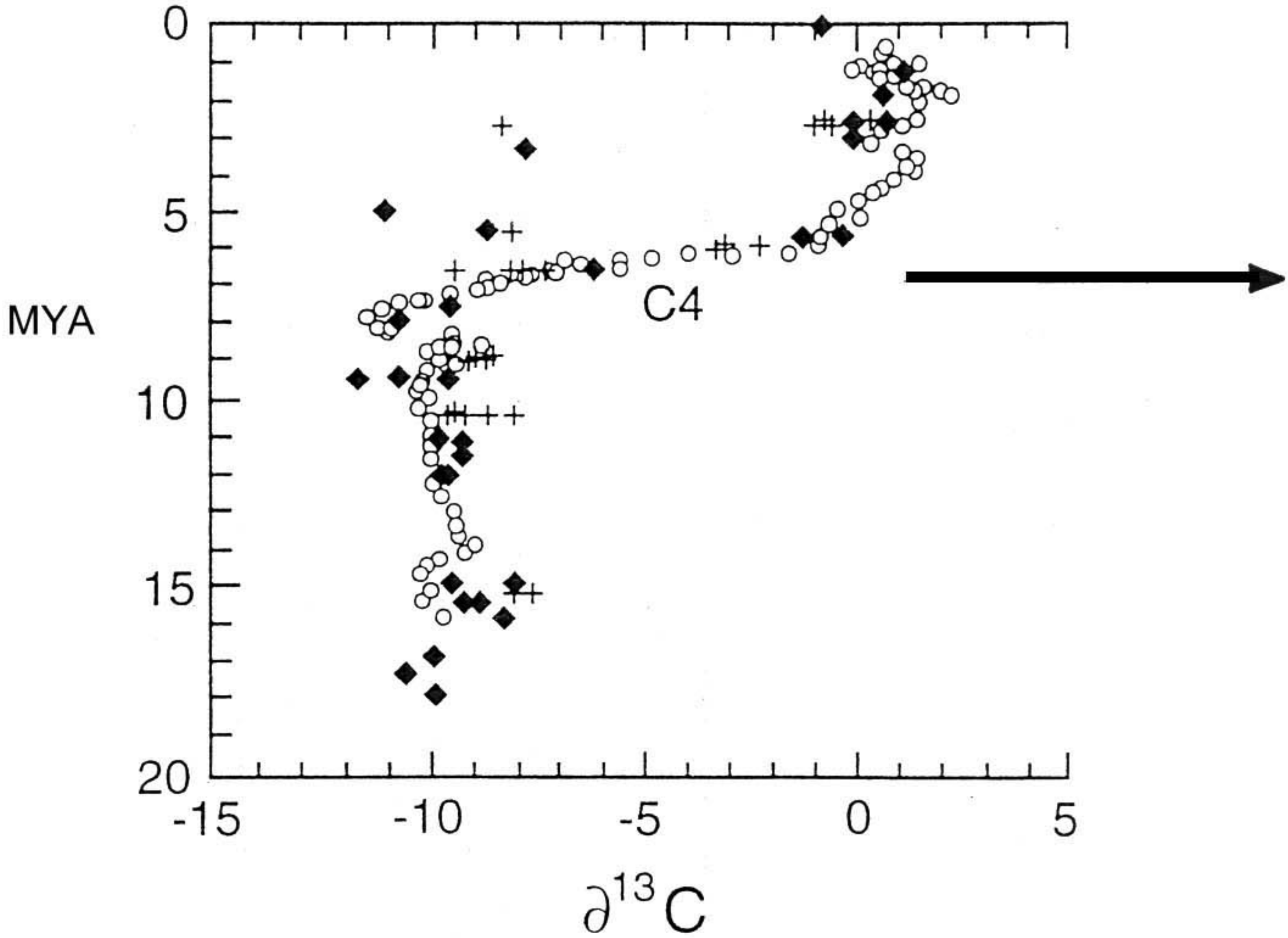
Ø hypso = hypsodont, or high crowned, having long teeth

Ø v hypso = very hypsodont

Ø the two hypsodont horse species of 6 mya are fossils found in the moist Gulf Coast region, low in C4 grasses

Ø there are seven species of horses living today around the world, all considered to have very hypsodont teeth

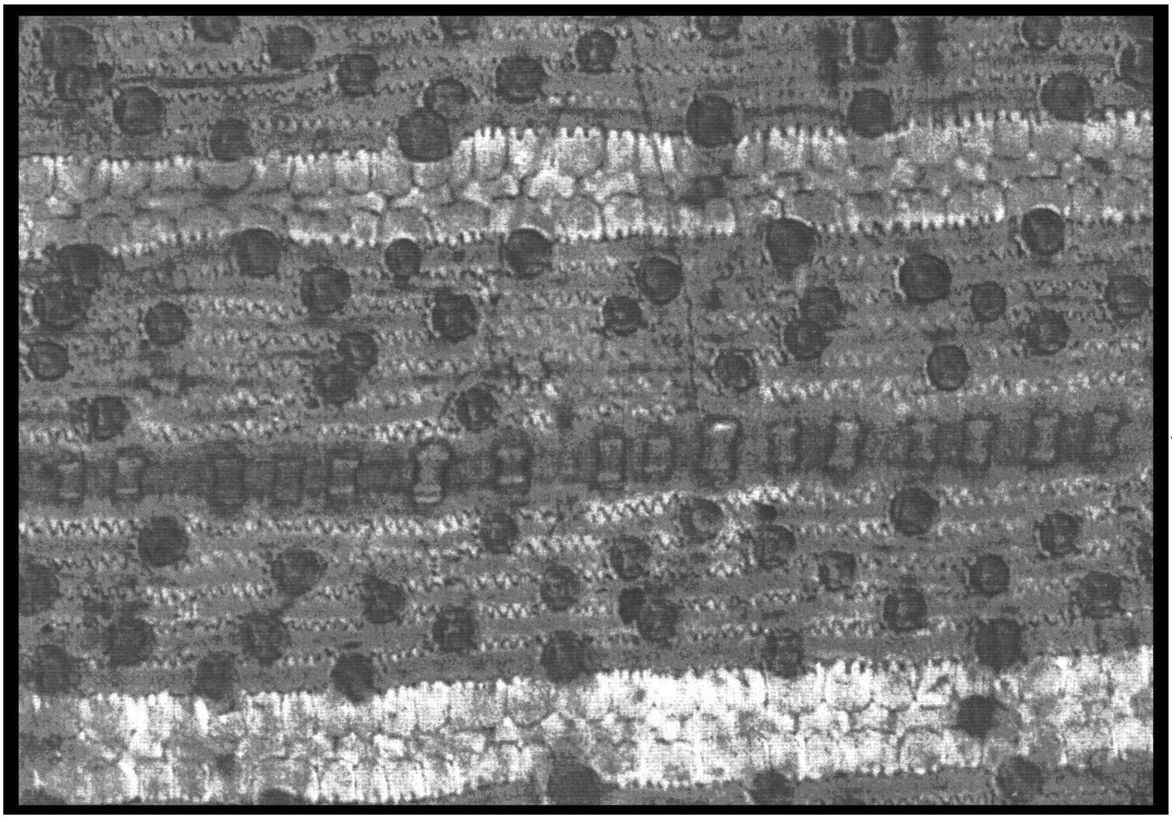
C4 Isotope Present in North American Fossil Horse Teeth



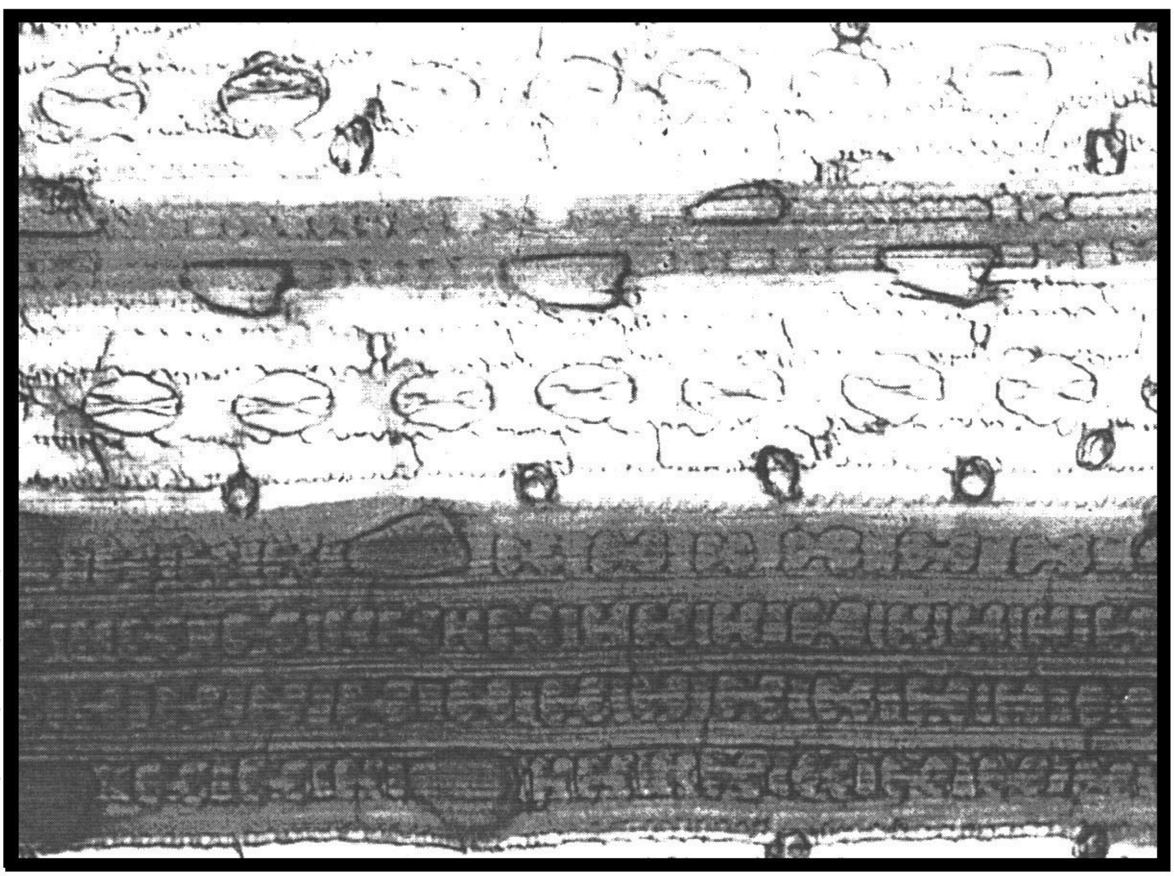
- the symbols on the chart represent three different studies; the circles from Cerling, 1993; the diamonds from Wang, 1994; the plusses from Latorre, 1996
- data points above do not match up directly with data from Chart One,
- C4 data above, from the three studies, are taken from horse fossil teeth found in the central and southwestern part of the continent
- the higher concentrations of C4 are to the right on the chart
- MYA = millions of years ago

LAB 4 - SHEET 6 ... C3 & C4 Grass Phytoliths

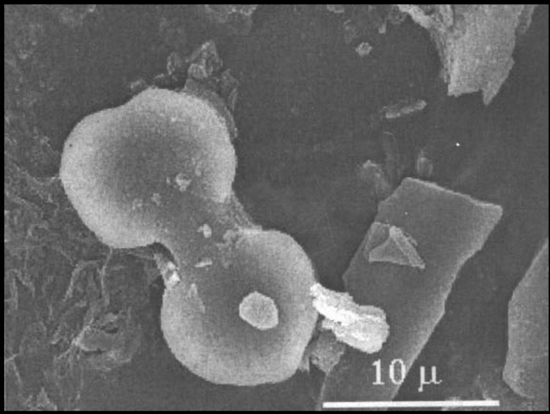
(from: http://www.bio.uu.nl/~palaeo/research/namibia/namibia.htm)



Oxytenanthera abyssinica **(C3 grass, South African Savanna)**

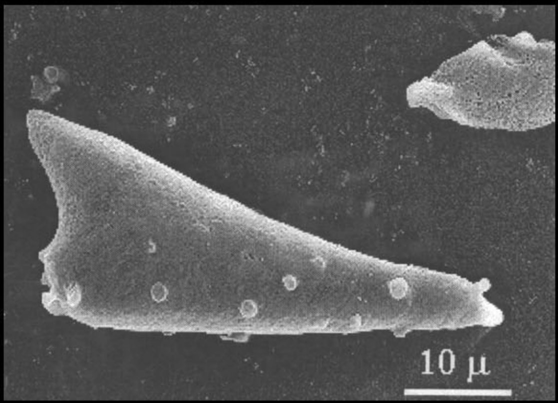


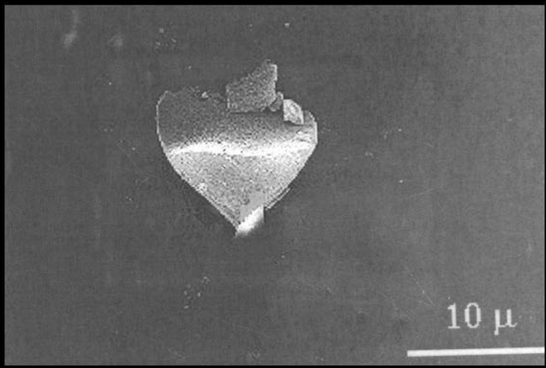
Ischaenum afrum **(C4 grass, South African Savanna & Grassland)**



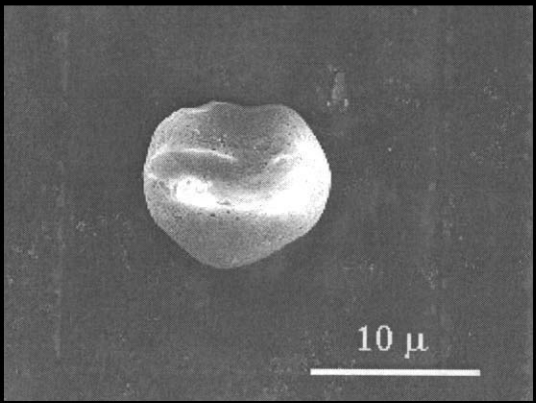
LAB 4 - SHEET 7 ... Examples of Grass Phytoliths

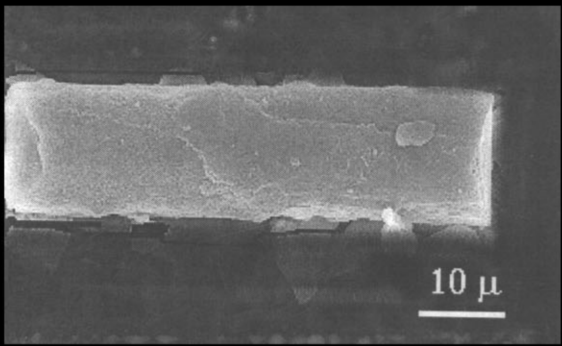
(from: http://coss.stcloudstate.edu/mblinnikov/phd/phyt.html)

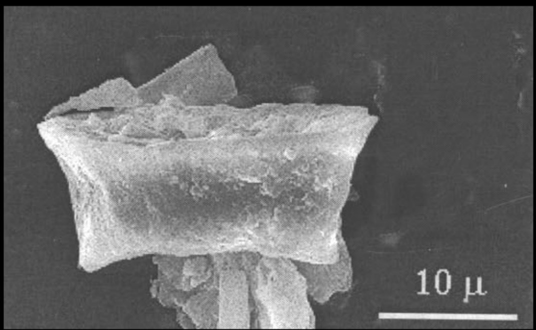


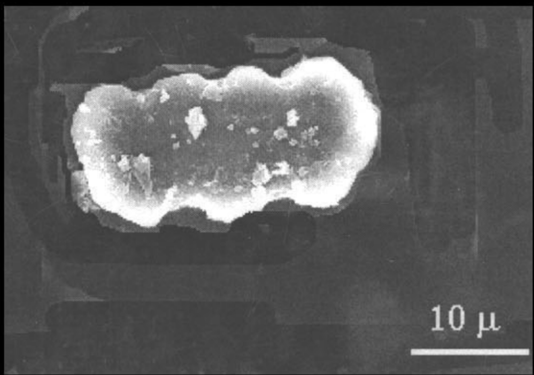


one micron is one-millionth of a meter   40 microns are visible without magnification   40-90 microns the width of a human hair









The original diagram that inspired Horse Kit - Lab 4. From the book Macro-Evolution – Pattern and Process, by Steven M. Stanley, Johns Hopkins University professor of paleobiology.

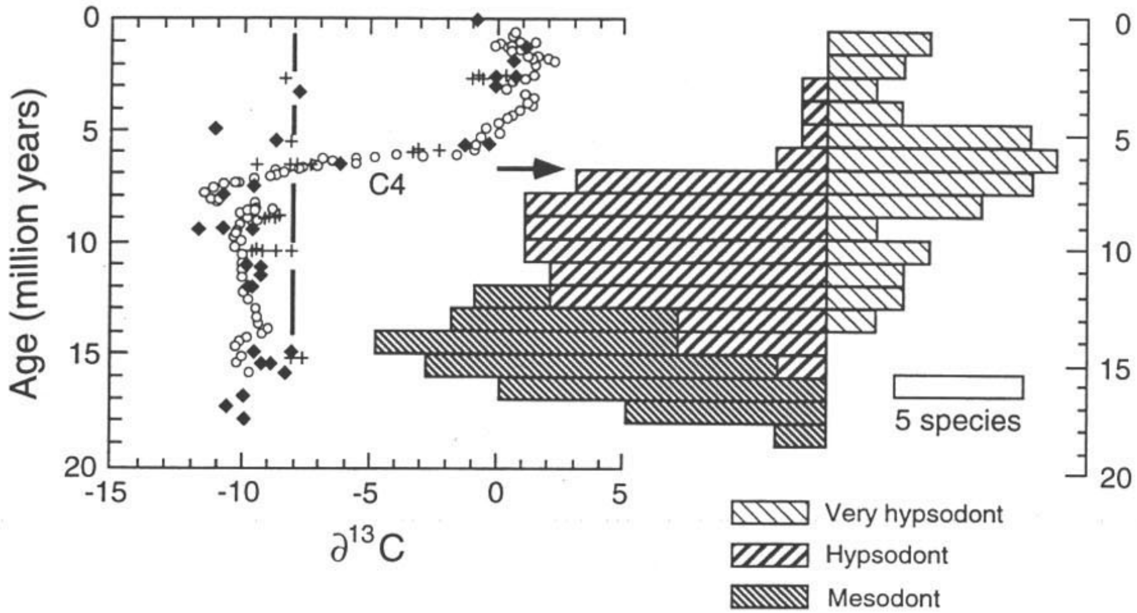


FIGURE P-4
Macroevolutionary change in mean molar length for North American horses. The trend between 18 and 7 million years ago resulted from species with relatively long teeth experiencing relatively high rates of speciation (Data from Hulbert, 1993.) The plot of carbon isotope ratios shows an abrupt shift toward heavier values between 7 and 6 million years ago in the central and southwestern United States. (Data from Cerling *et al.*, 1993 [circles]; Wang *et al.*, 1994 [diamonds]; and Latorre, 1996 [plus symbols]). This shift, which reflects the spread of highly siliceous C4 grasses into North America from the south, coincides with the extinction of most merely hypsodont species; the two surviving species survived in a moist Gulf Coast refuge.

LAB 4 - SHEET 8 Teacher Reference

LAB 4 – TEACHER REFERENCE

The internet sites listed below, with links, provide diverse research information for the teacher to prepare themselves before presenting the labs in the horse kit. Students involved in CIM & CAM could also be referred to these sites for research and lab preparation. The "Horses In Cyberspace" site is a wonderful place for students to explore.

LAB 4 Preparation: Teachers should definitely read the three articles listed in **bold and underlined** below in preparation for conducting LAB 4.

Generally, hit CONTROL & CLICK ON LINK to get to the website …

- Ø Horses in Cyberspace – http://www.flmnh.ufl.edu/natsci/vertpaleo/fhc/fhc.htm

- Ø Pony Express Newsletter – http://www.flmnh.ufl.edu/ponyexpress/pe_newsletters.htm

  - How to Identify Fossil Horses http://www.flmnh.ufl.edu/ponyexpress/pony1_1/Pe11.htm

  - How to identify Fossil Horses http://www.flmnh.ufl.edu/ponyexpress/pony1_2/Pe12.htm

  - How to Identify Fossil Horses http://www.flmnh.ufl.edu/ponyexpress/pony1_3/Pe13.htm

  - Sex in Fossil Horses & Pseudo Horses http://www.flmnh.ufl.edu/ponyexpress/pony1_4/Pe14.htm

  - Geographic Variation in Horses http://www.flmnh.ufl.edu/ponyexpress/pony2_2/Pe22.htm

  - Horse Phylogeny & **Mammal Tooth Structure** http://www.flmnh.ufl.edu/ponyexpress/pony2_3/Pe23.htm

  - How Can Horses Stand for so Long? http://www.flmnh.ufl.edu/ponyexpress/

pony2_4/Pe24.htm

- **Fossil Horses and Global Environmental Changes** & Horse Anatomy http://www.flmnh.ufl.edu/ponyexpress/pony3_1/pe31.htm

- **Fossil Horses and the Great American Interchange** & Horse Bones – The Ulna and Radius http://www.flmnh.ufl.edu/ponyexpress/pony3_2/PE32.HTM

- Why Do Zebras Have Stripes? http://www.flmnh.ufl.edu/ponyexpress/PONY4_1/PONY.HTM

- Building a Fossil Pit in Your Schoolyard http://www.flmnh.ufl.edu/ponyexpress/pony6_1/Pe61.htm

- The Last Decade (more or less) of Equid Paleobiology http://www.flmnh.ufl.edu/ponyexpress/pony13_2/Pe132.html

The sites above link to the University of Florida's Museum of Natural History. Dr. Bruce MacFadden, perhaps the world's foremost expert in horse fossils, has visited the John Day Fossil Beds many times in the past. He was very glad to see that we are referencing his research information in the National Park Service horse kit.

http://www.pbs.org/wgbh/evolution/library/03/3/l_033_01.html

- Horse Skeleton Diagram
http://www.fofweb.com/Subscription/Science/Science-Detail.asp?SID=1&iPin=A0830

- University of California, on Potassium Argon Dating, with Movies
http://id-archserve.ucsb.edu/Anth3/Courseware/Chronology/09_Potassium_Argon_Dating.html#Genesis

- German Site with some Good Plate Tectonic Diagrams
http://www.merian.fr.bw.schule.de/Beck/skripten/13/bs13-31.htm

- National Academy of Sciences, Teaching About Evolution and the Nature of

Science
http://www.nap.edu/readingroom/books/evolution98/contents.html

http://images.google.com/imgres?imgurl=http://www3.interscience.wiley.com:8100/legacy/college/levin/0470000201/chap_tutorial/ch05/images/le05_27.gif&imgrefurl=http://www3.interscience.wiley.com:8100/legacy/college/levin/0470000201/chap_tutorial/ch05/chapter05-4.html&h=432&w=303&sz=48&tbnid=DKtnBFSs3cMJ:&tbnh=123&tbnw=86&start=26&prev=/images%3Fq%3Dmesosaurus%26start%3D20%26hl%3Den%26lr%3D%26sa%3DN

- Exploring the Creation/Evolution Controversy: Dating Methods

http://www.talkorigins.org/faqs/faq-age-of-earth.html#constant

- American Scientific Affiliation (ASA), science in Christian perspective

http://www.asa3.org/index.html

http://www.blm.gov/education/00_resources/articles/wild_bunch/index.html

LAB 5: Plate Tectonics and Horses (Teacher Directions)

OVERVIEW: Students will use the evidence of fossils, rocks and minerals to assemble nine land tectonic plates together as they may have been 250 million years ago, a land mass we call Pangea (or Pangaea). Later in the lab, older students will study the effects moving land plates had on the family tree of horses.

ODOE STANDARDS: Lab 5 has been designed for use by Benchmark 3 (Grade 8) and above for about two-thirds of the lab. The last part is designed for CIM/CAM students.

Earth and Space Science: Understand physical properties of the Earth, how those properties change, and the Earth's relationship to other celestial bodies.

Common Curriculum Goal: Understand changes occurring within the lithosphere, hydrosphere, and atmosphere of the Earth.

Benchmark 3 (Grade 8) – Describe the evidence for and the development of the theory of plate tectonics.

CIM/CAM – Use rock sequences and fossil evidence to determine geologic history.

TIME LIMITS: We estimate Lab 5 taking about 45 minutes, the last 10 minutes made up of the CIM/CAM study.

TEACHER PREPARATION BEFORE LAB: Before the lab begins the teacher should prepare the following items.

- Ø We suggest that the class be broken up into smaller discussion groups, with no more than six students per group. Assign a leader for each group. Each group will gather around a table on which they will assemble a paper model of Pangea and discuss their findings. Each group leader should have a copy of the LAB 5 – SHEET 1 Student Directions, to allow the groups to follow along with the teacher's directions.

- Ø For each group, each table, make a copy of LAB 5 – SHEET 2 and SHEET 3. Before the class, have a member of each group cut out the nine landforms on SHEET 3, and have the cutouts ready for the LAB 5 work in class.

Ø For each table have a sheet of paper and tape. On the paper have a straight line drawn down the center, which will act as the equator.

Ø The CIM/CAM students will need a copy of the LAB 1 – SHEET 2, horse family tree as a reference, one per table.

Ø Make a copy of LAB 5 – SHEET 4, 5 & 6 for teacher references. They may be useful as handouts during the class discussion.

Ø A large globe, readily available in class, will make a good reference showing the path of the tectonic plates around the sphere.

CLASSROOM WORK BEGINS HERE: (part one)

Your student group should conduct this study of Pangea, the large super-continent that existed 250 million years ago. The teacher will verbally give directions to the class, based upon these directions. The leader at each table should have a copy to follow along with, and then lead the group.

STEP ONE: Each student group should be seated at their own table, each table having the nine pieces of the Pangea puzzle. Use the classroom globe as reference as needed by your group. The nine, landmass pieces have been drawn from a globe (a sphere), so the sizes of the pieces are in proper proportion to each other.

1. Take the sheet of paper with the single line drawn down the center, and tape the paper to the table top where it is easy for all to reach. The line on the paper will represent the equator.

2. Take out the nine puzzle pieces and lay them on the table. Lay the Africa piece on your equator line, lining up the 250 mya equator with the equator line on your taped-down paper.

The various landmass pieces show some of the rock and mineral, fossil deposits, and remnants of mountain ranges, we find on the planet today dated 250 million years in age.

Mountain ranges that had similar geologic features, age, minerals composition, erosion wear, etc., have the same number. They are numbered 1 through 4.

The mineral and rock deposits have letters which mean the following:

C = Coal deposits S = Salt G = Gypsum L = desert sandstone layers

2. Look at the four color drawings of the types of fossils found in the 250 million year old deposits, LAB 5 – SHEET 2. Lay the drawings out for your reference on the table.

The drawings are color-coded, four colors being used; green, orange, blue, and yellow. The color areas on the landform pieces are where fossils of the same animal or plant have been found today, matching the color-coded drawings.

Keep in mind that each color represents one type of plant or animal, and each plant or animal would have had a large population. Each population would have lived in in contact with each other, one area of the planet, not in separate areas. This means that you need to connect all of the same colored areas together.

3. Identify the nine pieces by name, matching them with landmasses currently on the planet. (The student in your group who cut them out should be able to name them.)

4. Using the fossil deposits, rock and mineral deposits, mountain ranges, and the general shape of the continents, arrange the nine puzzle pieces on the desktop into one large landmass. This one landmass will represent Pangea about 250 million years ago. The shape of each piece is based upon their shape today. Back 250 mya their shapes were probably a bit different, so you may not get a perfect fit for your Pangea.

Remember that these nine pieces had to drift on the planet to get to where they are today. The way you put them together has to allow for the pieces to drift to today's global position without having to plow through each other.

5. When you have finished putting the nine puzzle pieces together, compare your Pangea to the teacher's Pangea drawing. Make corrections in your Pangea puzzle to match the teacher's version.

STEP TWO: Once you have you table's puzzle assembled accurately you will then break up Pangea and drift the continents.

1. Note on the Africa puzzle piece there is a line that represents where we think the equator crossed Africa 250 million years ago. Where does the equator cross Africa today? (The equator is a human-created reference, and always runs east-west in direction, around the widest part of the globe midway between the poles.) By comparing

the equator line then and now, note how the location of Africa today has moved from its location 250 mya.

2. Use your Pangea puzzle on the table, you will pretend that the last 250 million years are passing again (but at a much quicker rate).

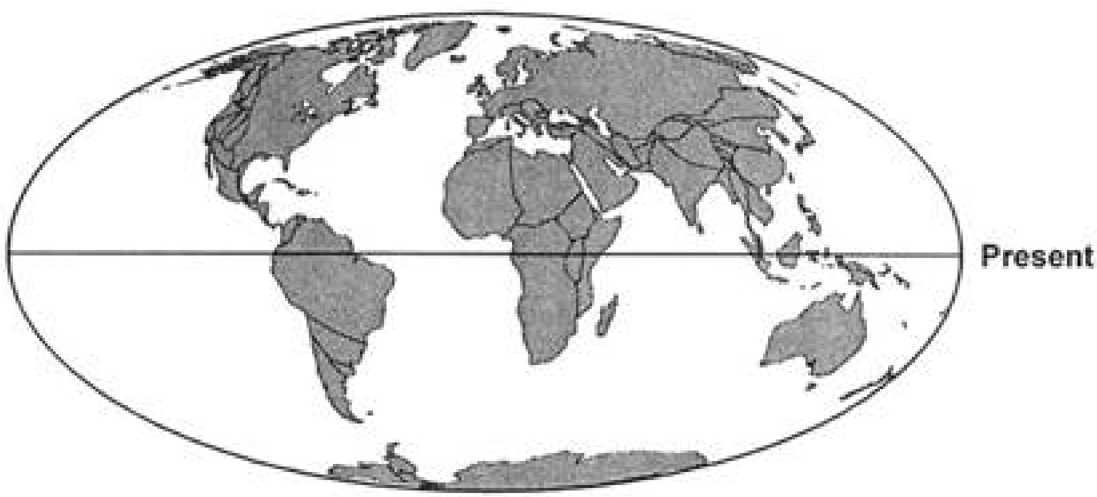
These discoveries about the continental drift may help you move your Pangea pieces more accurately.

a. Africa, Eurasia, North America, South America, and Greenland tended to stay together as a group for the first half of the 250 million year movement, drifting northwestward. In the second half, Africa tended to stay in the same spot on the planet, near where it is today.

b. Madagascar and India tended to stay in the same spot and stay together for the first half of the 250 million-year journey.

c. Antarctica and Australia stayed together and separated from the others immediately, heading southeast for the first half of their journey.

In small movements, move your nine Pangea puzzle pieces to their current position today. Use the globe to help direct your movements to where the landmasses are located today.



STEP THREE: Each group should assemble Pangea again, with their nine pieces. The teacher will lead a discussion of the following questions.

a. About how many miles can a continent travel in 50,000,000 years if it moves at the fairly average continental drift rate of one inch per year? (Name a large town to the east of you that many miles away.)

a. 52 miles b. 152 miles c. 530 miles d. 790 miles e. 5,280 miles
(the answer is the same as the first letter in the common name for a canine)

b. Just by looking at the outer shape of each of the nine pieces, do you see how well they tend to fit together as one big land mass called Pangea? Is it a perfect fit?

c. Did having the old mountain ranges, rock and mineral deposits, and fossil deposits help you to assemble the pieces into Pangea? Of the three, which were the most helpful to you?

STOP … CIM/CAM students should proceed. This completes the lab for Benchmark 3 (grade 8) students.

CIM/CAM STUDENTS CONTINUE: (part two)

STEP FOUR: Each group should look over their copy of LAB 1 – SHEET 2, the diagram of the horse family tree. In groups, or as a class, you will discuss the three questions below. The teacher has a copy of the answers.

Here is some information regarding the horse family tree diagram, and continental drift over time.

- OLD WORLD on the family tree diagram means Asia, Europe, and Africa

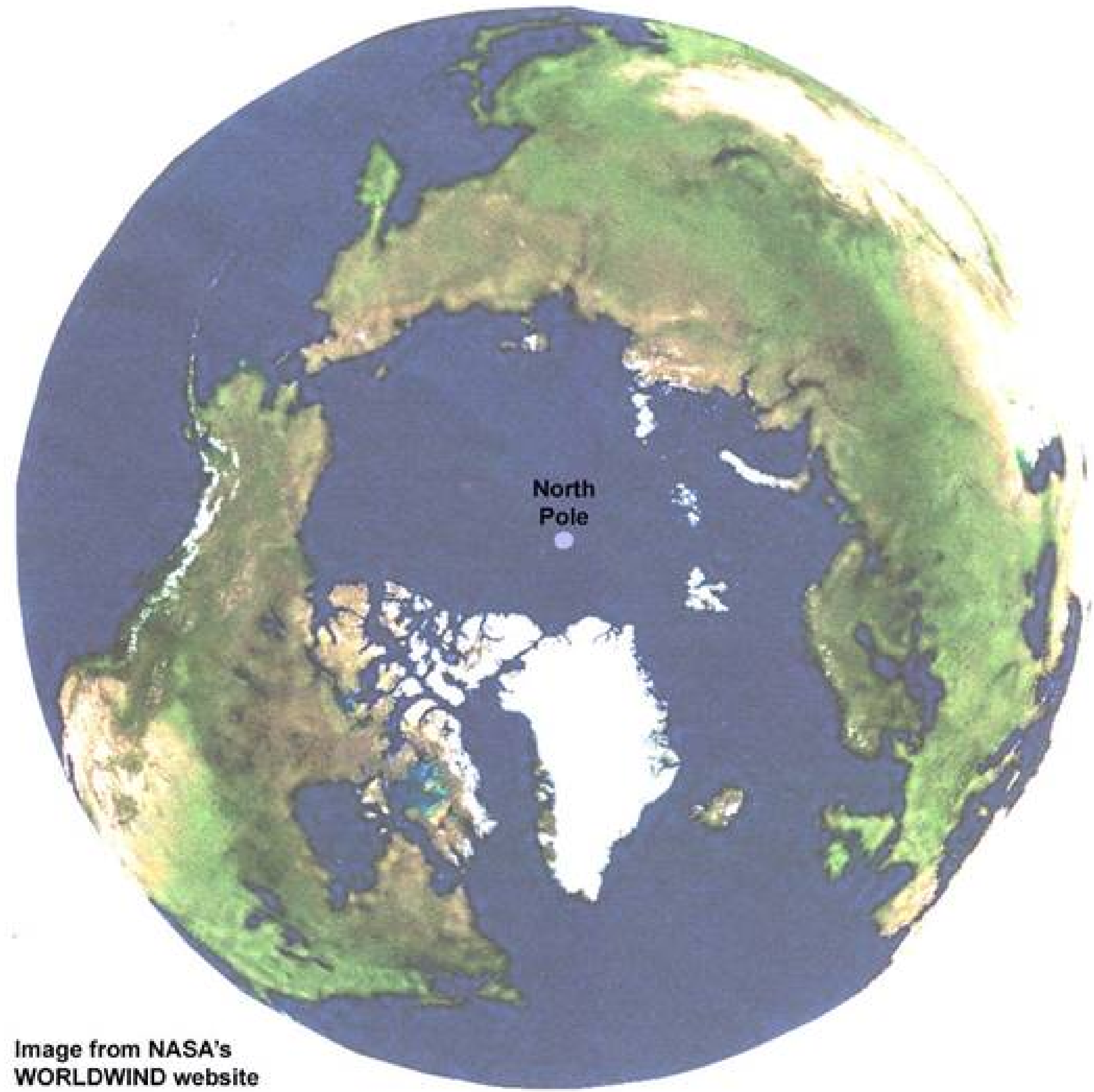
- The North American continent has drifted in the westward direction in the last 100 million years, with little variance north or south. Europe headed in the other direction, at a slower rate. The Atlantic Ocean continues to widen.

- In broad terms, the diagram indicates where in the world horse fossil have been found for different time periods in the past.

- Today, the distance between Labrador and Ireland is about 2,500 miles.

Ø At the latitude of Ireland, North America's drift has been about one inch per year, (actually it was probably a bit faster, but let's use one inch per year).

Ø Ocean levels have risen and dropped hundreds of feet, several times over the last 100 million years.



d. On the horse family tree diagram, for most of the 55 million year history, many types of horses freely and regularly migrated to the Old World from North America. Now, as far as we know, horses have never been able to walk on water or fly, perhaps swim a few dozen miles at most. What could explain the nearly 20 million year gap (42mya to 24 mya) when horses did not migrate to the Old World?

(**brief answer:** Possible answers include …

- Ø horses did not try to migrate to the Old World over the twenty million year period, even though the opportunity was there
- Ø they made the effort, arrived in the Old World, and died out so quickly few fossils if any formed to be found later
- Ø for twenty million years there was something that prevented the horses from making the move from one continent to another

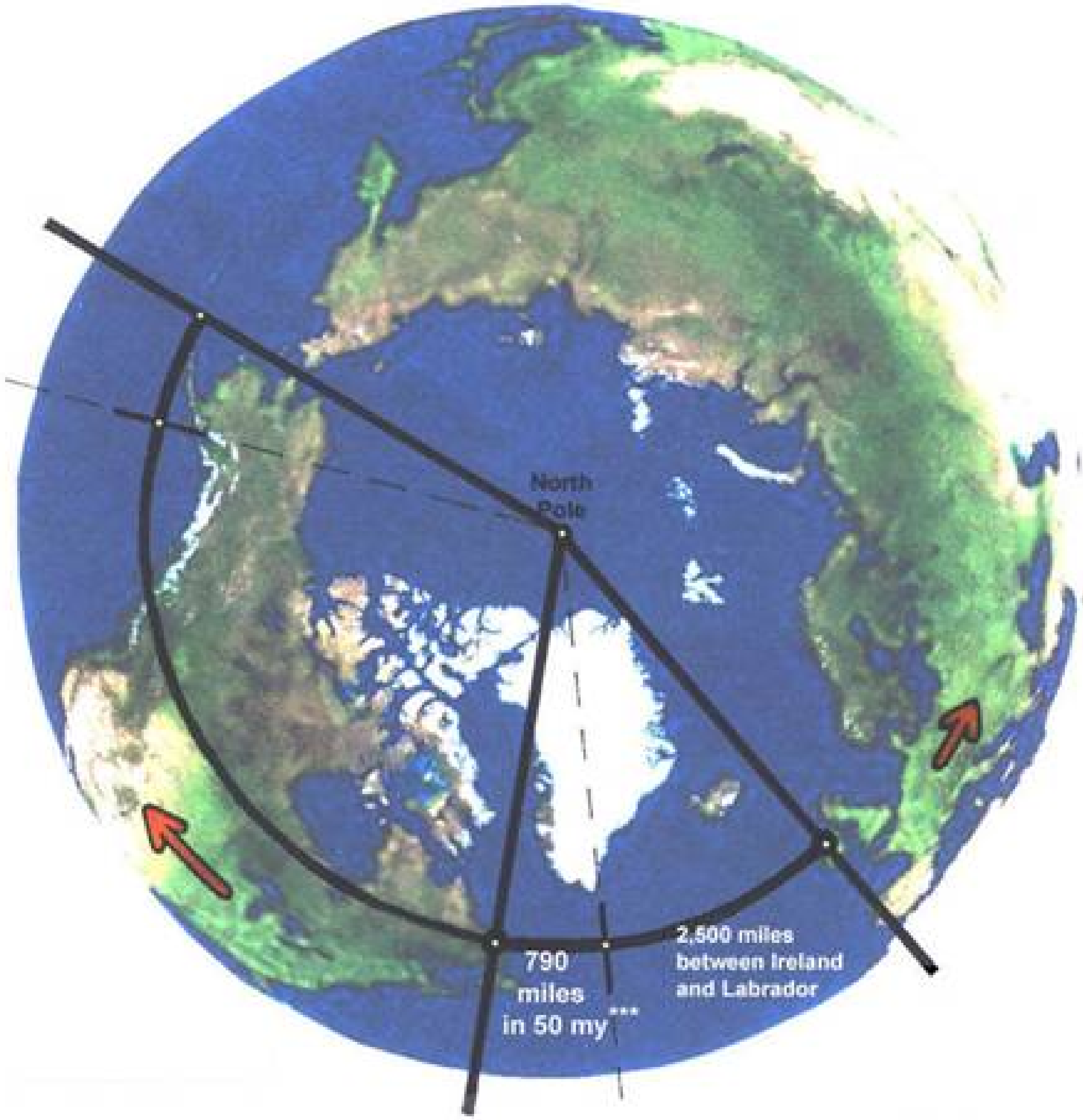
Twenty million years is a long time to not “try” to migrate, if an opportunity was available.

Considering the success* of horses migrating to and living in the Old World before and after the 20 my gap, it hard to imagine what would cause such an extremely long period of immediate annihilation of horses soon after they arrived in the Old World. There is no fossil evidence of creatures in the Old World waiting for the horses and killing them off.

** Even though they may have lived only five or more million years before extinction, that should be considered a successful migration and establishment of a viable population [resulting in a small percentage of the dead becoming fossils to be discovered later].*

The most probable explanation is that for a period of 20 my there was something long-lasting, significant, and tremendously broad in scope that prevented the horses from migrating from one continent to another. That would generally mean something not-living. Looking at the world today, one has to wonder how a horse might migrate from one continent to another, and we would conjecture that they would make use of land bridges that were available. So if the land bridges did not exist that means large bodies of water would prevent horse migration today. Large bodies of water preventing migration seem the likely reason for the 20 my gap when horse did not migrate from North America to the Old World.)

e. What land bridges did horses use to migrate to the Old World?



(**brief answer:** Based upon the earth diagram above, and the LAB 5 – Sheet 4 & Sheet 5 diagrams, there is evidence of two land bridges that have existed in the last 55 million years between North America and the Old World, the Bering Land Bridge and the DeGeer Land Bridge. Neither of these land bridges probably existed in the 20 my gap we are addressing, due to continental drift. The earth diagram below shows how a water gap may have existed between North America and the Old World sometime during the drift of North America westward over the last 50 million years, and this at a conservative drift rate of one inch per year. We think the rate of drift may have been faster, even up to two inches or more per year at times.

Looking at the horse family tree diagram, the horses that migrated to the Old World before 42 mya probably migrated across the DeGeer Land Bridge entering first into Europe. Then North America separated from the Old World, the DeGeer Land Bridge became water, and the future Bering Land Bridge was still a broad body of water. Horses were land-locked on North America, until the first of the Bering Land Bridges [with a lowering of the ocean level] established about 24 mya, and horses entered the Old World via Siberia.)

f. Based upon the family tree, when do you think South America and North America last connected?

(**brief answer:** After Pangea broke up and the North and South America last touched about 150 mya, the horse family tree diagram seems to indicate that South America and North America contacted each other with a land bridge about 4-3 mya. North America had been moving westward and South America was moving northwestward when they touched again. After this contact animals from both continents interchanged and mixed in what paleontologists call the “Great American Interchange.” You will note that the horse later became extinct in South America about the same time they did in North America, during the last ice age.)

STOP … CIM/CAM Students have completed LAB 5.

LAB 5 – SHEET 1: Plate Tectonics and Horses (Student Directions)

OVERVIEW: Students will use the evidence of fossils, rocks and minerals to assemble nine land tectonic plates together as they may have been 250 million years ago, a land mass we call Pangea (or Pangaea). Later in the lab, older students will study the effects moving land plates had on the family tree of horses.

TIME LIMITS: We estimate Lab 5 taking about 45 minutes, the last 10 minutes made up of the CIM/CAM study.

CLASSROOM WORK BEGINS HERE: (part one)

Your student group should conduct this study of Pangea, the large super-continent that existed 250 million years ago. The teacher will verbally give directions to the class, based upon these directions. The leader at each table should have a copy to follow along with, and then lead the group.

STEP ONE: Each student group should be seated at their own table, each table having the nine pieces of the Pangea puzzle (cut from LAB 5 – SHEET 3). Use the classroom globe as reference as needed by your group. The nine, landmass pieces have been drawn from a globe (a sphere), so the sizes of the pieces are in proper proportion to each other.

1. Take a blank sheet of paper with the single line drawn down the center, and tape the paper to the table top where it is easy for all to reach. The line on the paper will represent the equator.

2. Take out the nine puzzle pieces and lay them on the table. Lay the Africa piece on your equator line, lining up the 250 mya equator with the equator line on your taped-down paper.

The various landmass pieces show some of the rock and mineral, fossil deposits, and remnants of mountain ranges, we find on the planet today dated 250 million years in age.

Mountain ranges that had similar geologic features, age, minerals composition, erosion wear, etc., have the same number. They are numbered 1 through 4.

The mineral and rock deposits have letters which mean the following:

C = Coal deposits S = Salt G = Gypsum L = desert sandstone layers

3. Look at the four color drawings of the types of fossils found in the 250 million year old deposits, LAB 5 – SHEET 2. Lay the drawings out for your reference on the table.

The drawings are color-coded, four colors being used; green, orange, blue, and yellow. The color areas on the landform pieces are where fossils of the same animal or plant have been found today, matching the color-coded drawings.

Keep in mind that each color represents one type of plant or animal, and each plant or animal would have had a large population. Each population would have lived in in contact with each other, one area of the planet, not in separate areas. This means that you need to connect all of the same colored areas together.

4. Identify the nine pieces by name, matching them with landmasses currently on the planet. (The student in your group who cut them out should be able to name them.)

5. Using the fossil deposits, rock and mineral deposits, mountain ranges, and the general shape of the continents, arrange the nine puzzle pieces on the desktop into one large landmass. This one landmass will represent Pangea about 250 million years ago. The shape of each piece is based upon their shape today. Back 250 mya their shapes were probably a bit different, so you may not get a perfect fit for your Pangea.

Remember that these nine pieces had to drift on the planet to get to where they are today. The way you put them together has to allow for the pieces to drift to today's global position without having to plow through each other.

6. When you have finished putting the nine puzzle pieces together, compare your Pangea to the teacher's Pangea drawing. Make corrections in your Pangea puzzle to match the teacher's version.

STEP TWO: Once you have you table's puzzle assembled accurately you will then break up Pangea and drift the continents.

1. Note on the Africa puzzle piece there is a line that represents where we think the equator crossed Africa 250 million years ago. Where does the equator cross Africa today? (The equator is a human-created reference, and always runs east-west in direction, around the widest part of the globe midway between the poles.) By comparing the equator line then and now, note how the location of Africa today has moved from its location 250 mya.

2. Use your Pangea puzzle on the table, you will pretend that the last 250 million years are passing again (but at a much quicker rate).

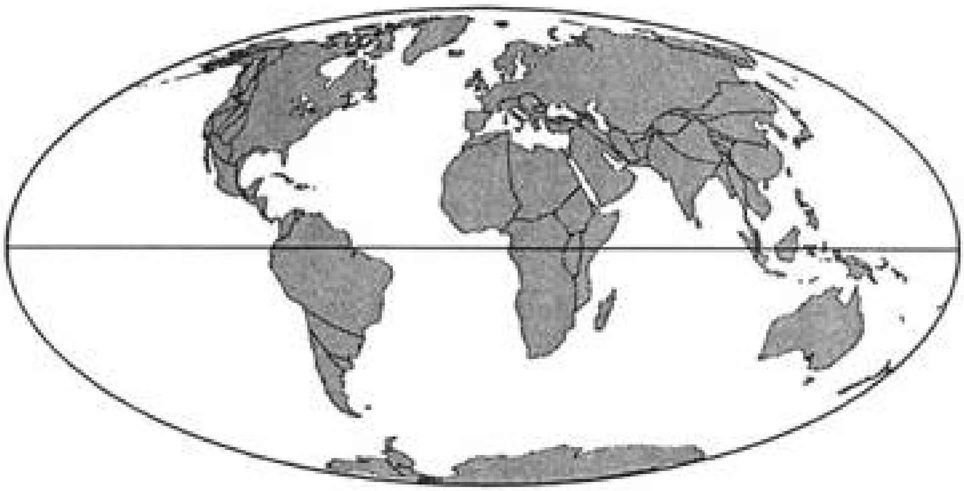
These discoveries about the continental drift may help you move your Pangea pieces more accurately.

a. Africa, Eurasia, North America, South America, and Greenland tended to stay together as a group for the first half of the 250 million year movement, drifting northwestward. In the second half, Africa tended to stay in the same spot on the planet, near where it is today.

b. Madagascar and India tended to stay in the same spot and stay together for the first half of the 250 million-year journey.

c. Antarctica and Australia stayed together and separated from the others immediately, heading southeast for the first half of their journey.

In small movements, move your nine Pangea puzzle pieces to their current position today. Use the globe to help direct your movements to where the landmasses are located today.



STEP THREE: Each group should assemble Pangea again, with their nine pieces. The teacher will lead a discussion of the following questions.

a. About how many miles can a continent travel in 50,000,000 years if it moves at the fairly average continental drift rate of one inch per year? (Name a large town to the east of you that many miles away.)

a. 52 miles b. 152 miles c. 530 miles d. 790 miles e. 5,280 miles
(the answer is the same as the first letter in the common name for a canine)

b. Just by looking at the outer shape of each of the nine pieces, do you see how well they tend to fit together as one big land mass called Pangea? Is it a perfect fit?

c. Did having the old mountain ranges, rock and mineral deposits, and fossil deposits help you to assemble the pieces into Pangea? Of the three, which were the most helpful to you?

STOP … CIM/CAM students should proceed. This completes the lab for Benchmark 3 (grade 8) students.

CIM/CAM STUDENTS CONTINUE: (part two)

STEP FOUR: Each group should look over their copy of LAB 1 – SHEET 2, the diagram of the horse family tree. In groups, or as a class, you will discuss the three questions below. The teacher has a copy of the answers.

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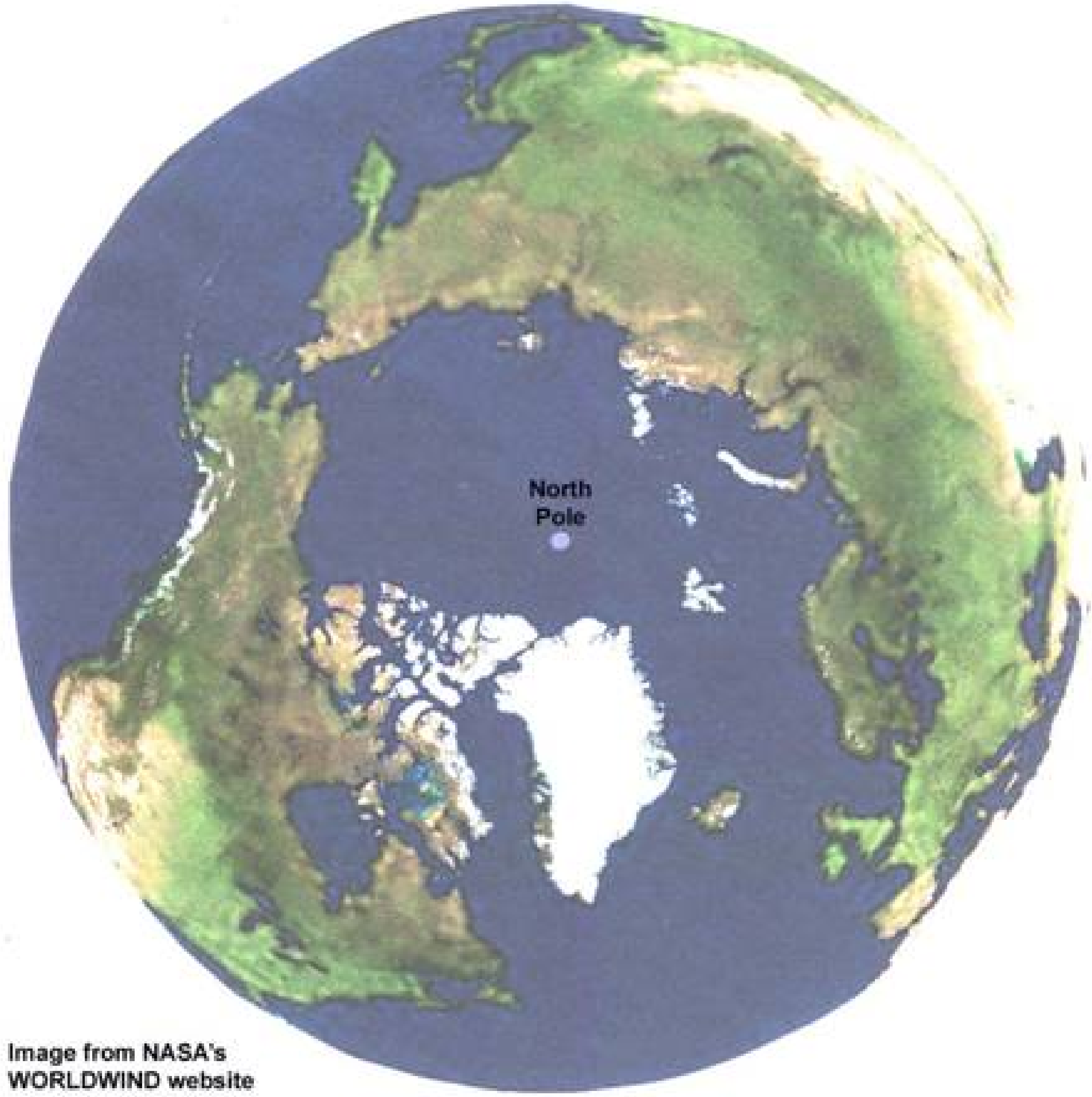
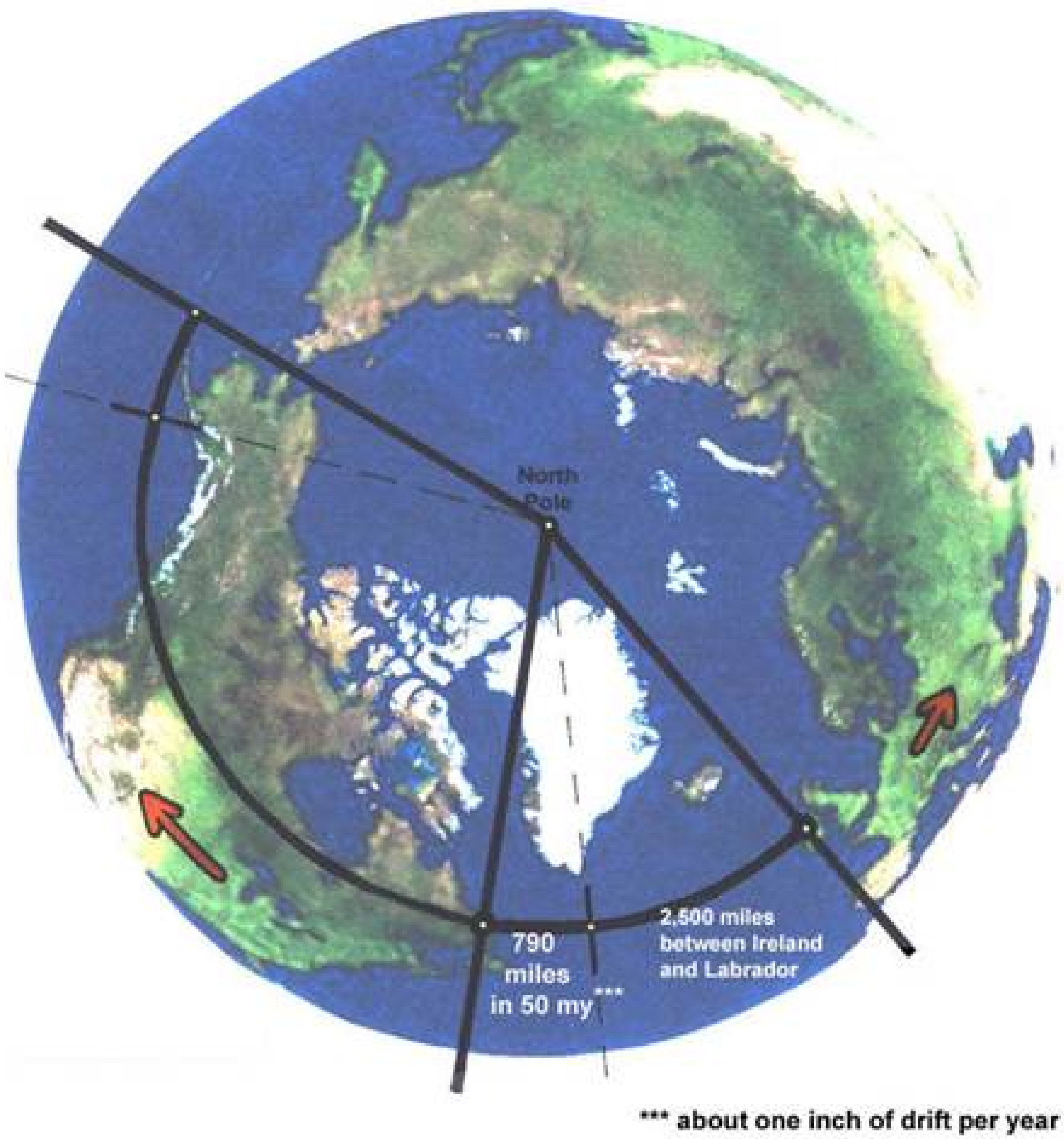


d. On the horse family tree diagram, for most of the 55 million year history, many types of horses freely and regularly migrated to the Old World from North America. Now, as far as we know, horses have never been able to walk on water or fly, perhaps swim a few dozen miles at most. What could explain the nearly 20 million year gap (42mya to 24 mya) when horses did not migrate to the Old World?

e. What land bridges did horses use to migrate to the Old World?

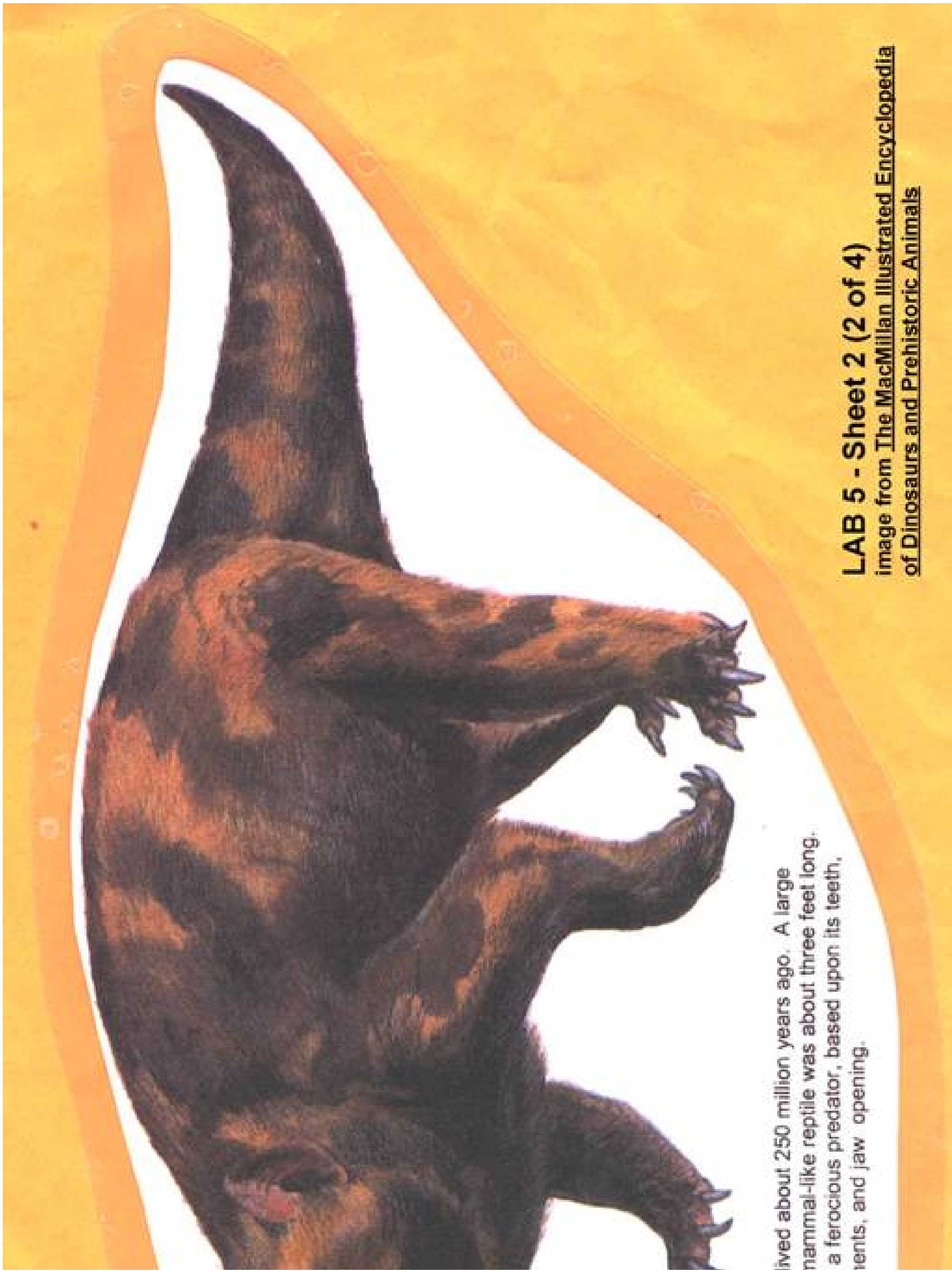


f. Based upon the family tree, when do you think South America and North America last connected?

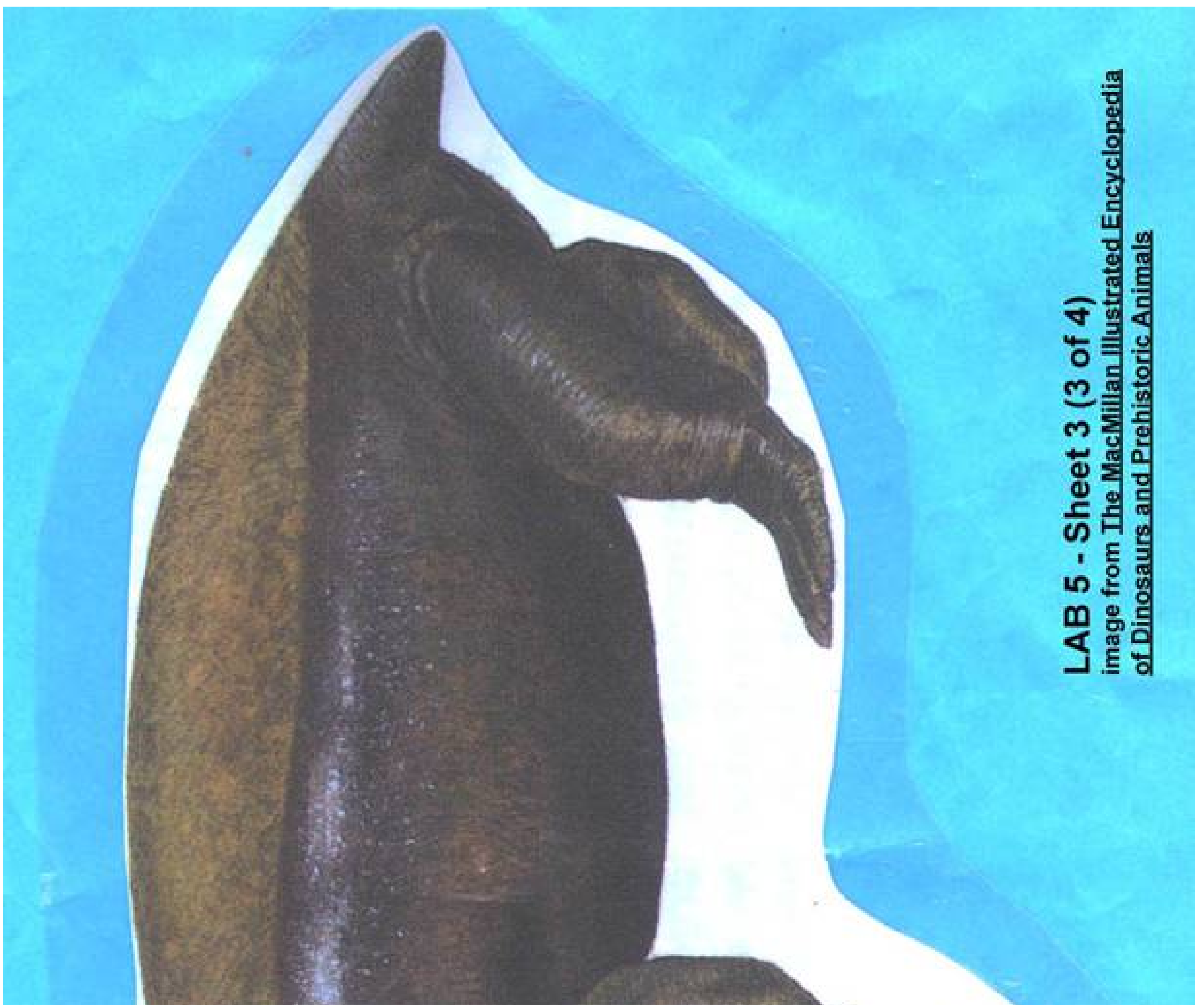
STOP ... CIM/CAM Students have completed LAB 5.


LAB 5 - Sheet 2 (1 of 4)
image from The MacMillan Illustrated Encyclopedia of Dinosaurs and Prehistoric Animals
MESOSAURUS
Mesosaurus lived about 280 million years ago and measured up to three feet long. This was the first reptile to revert back to

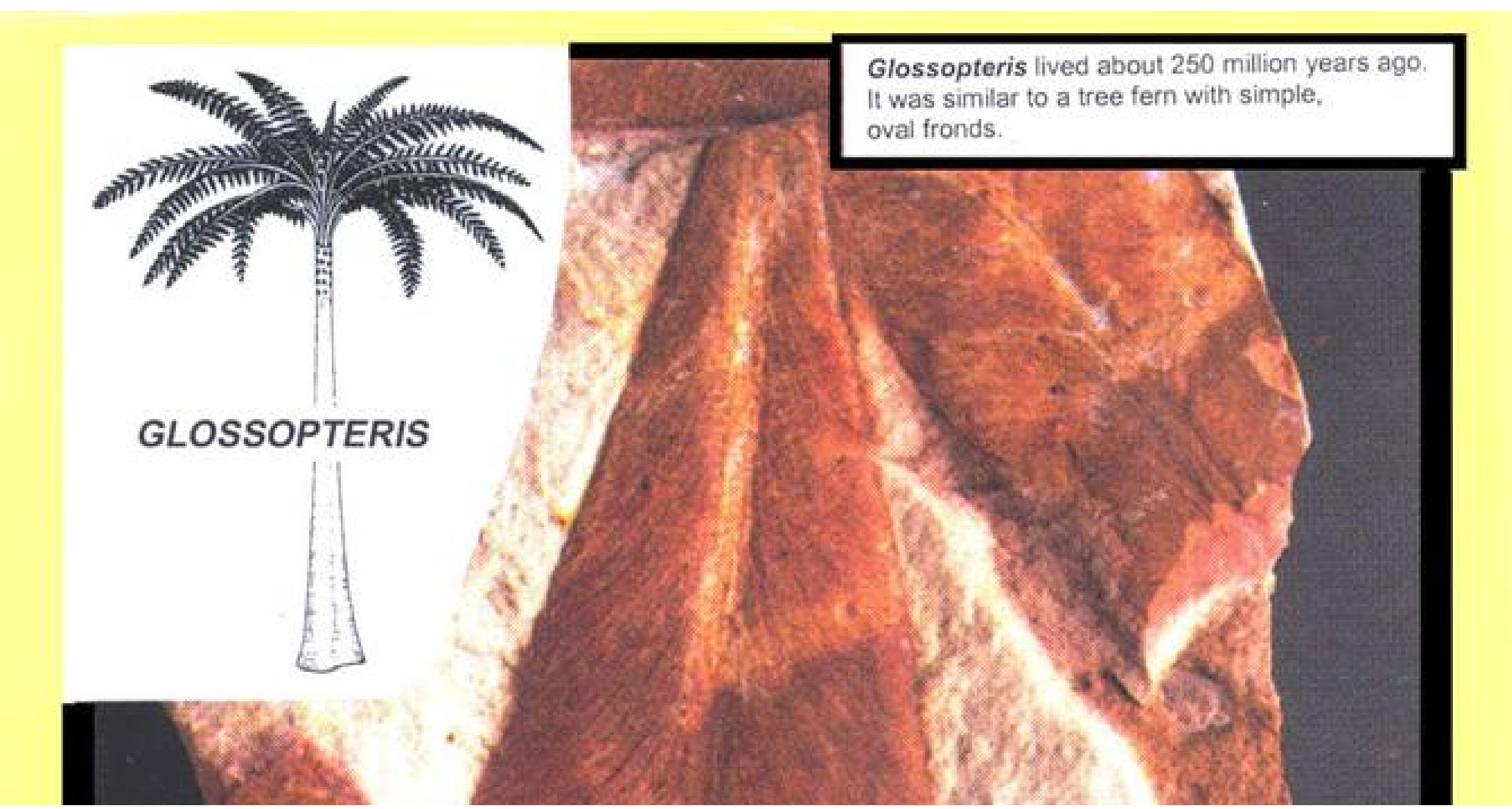
ago and measured up to three feet long. This was the first reptile to revert back to a water-dwelling existence, possessing many adaptations to aquatic life. It probably lived in freshwater or shoreline areas.

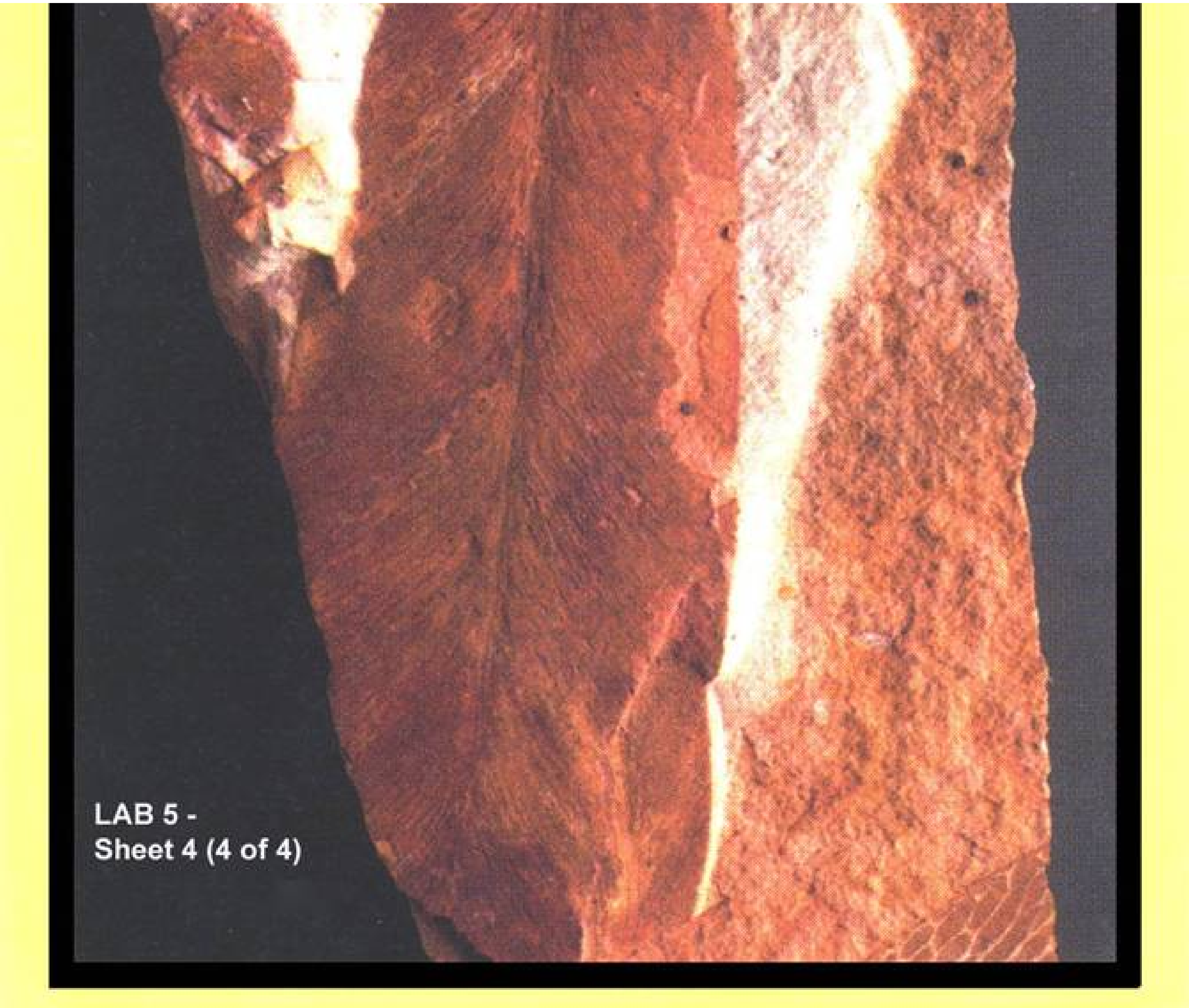



CYNOGNATHUS
Cynognathus lived
cynodont, this mamr
It was probably a fe
muscle attachments,


LAB 5 - Sheet 3 (3 of 4)
image from The MacMillan Illustrated Encyclopedia
of Dinosaurs and Prehistoric Animals

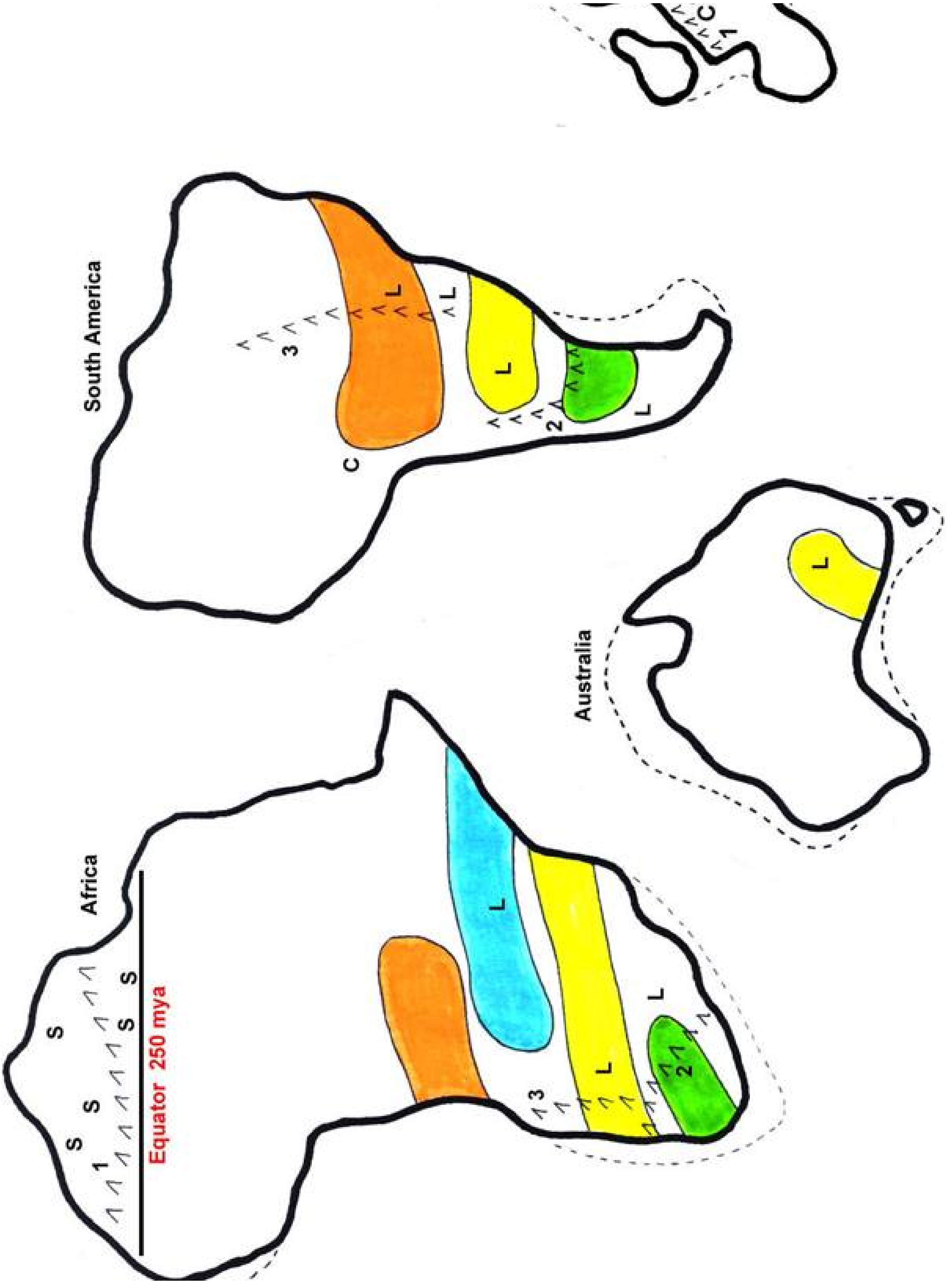

LYSTROSAURUS
Lystrosaurus lived about 250 million years ago and was about three feet long. This plant-eater was probably a kind of a reptilian "hippo" browsing on shallow water plants. Its nostrils were placed far back on the skull near the eyes to allow this water browsing.

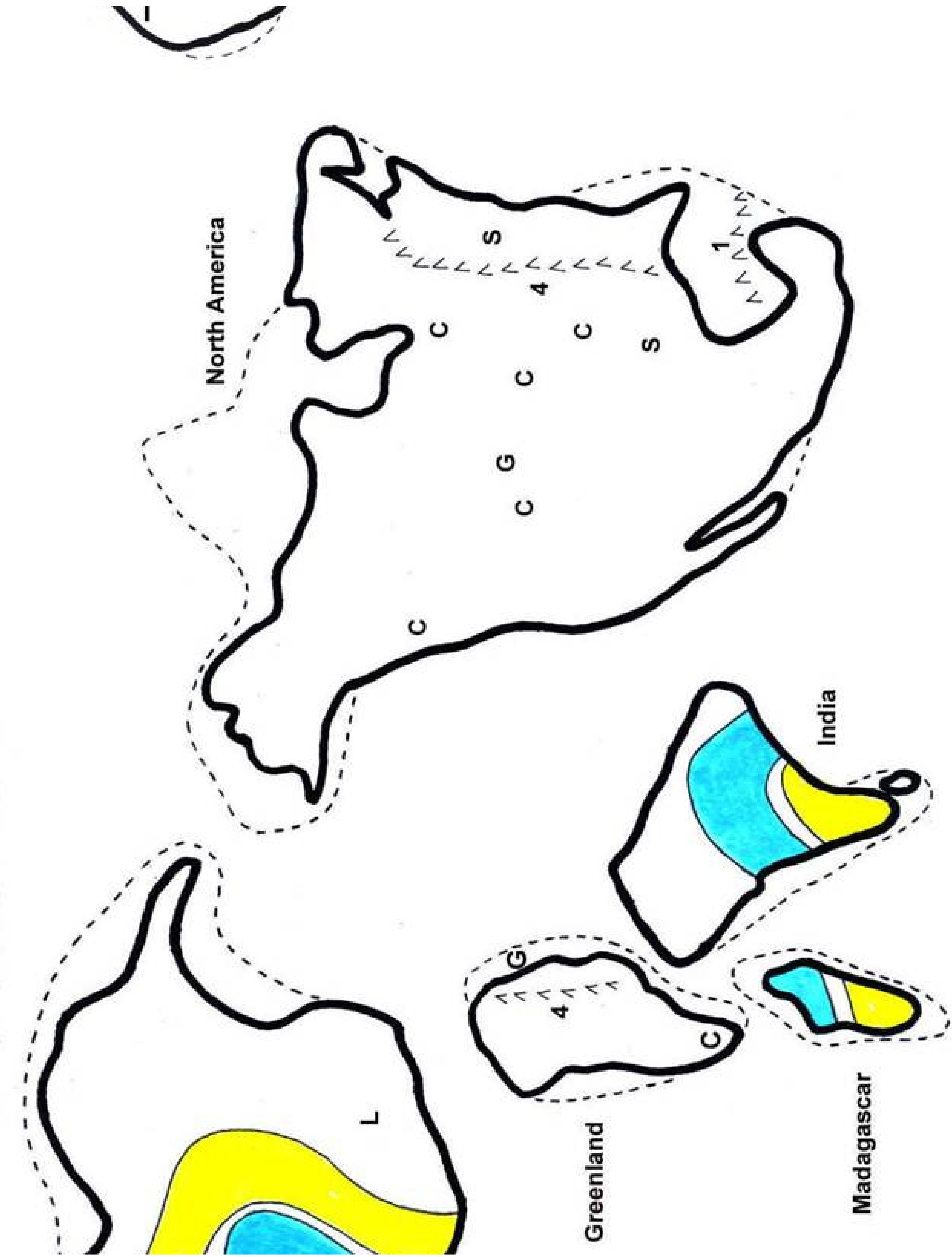

Glossopteris lived about 250 million years ago. It was similar to a tree fern with simple, oval fronds.
GLOSSOPTERIS


LAB 5 -
Sheet 4 (4 of 4)

LAB 5 – Sheet 3:

Nine Landforms, on three pages, to cut out and make Pangea as it was 250 mya.


South America
Africa
Australia
Equator 250 mya


North America
S
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India
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Greenland
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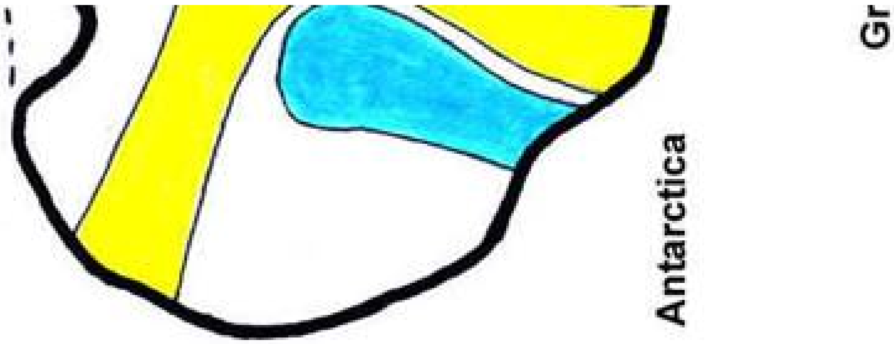
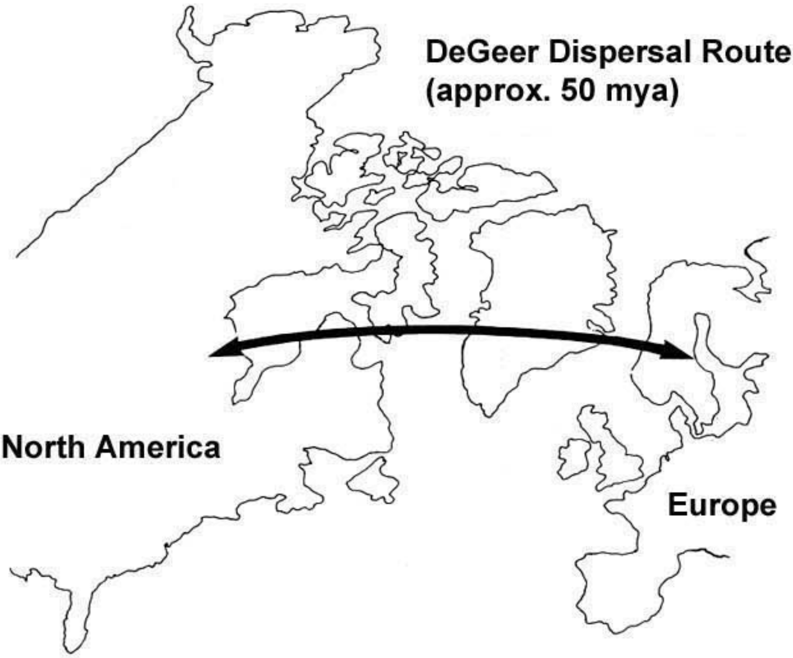
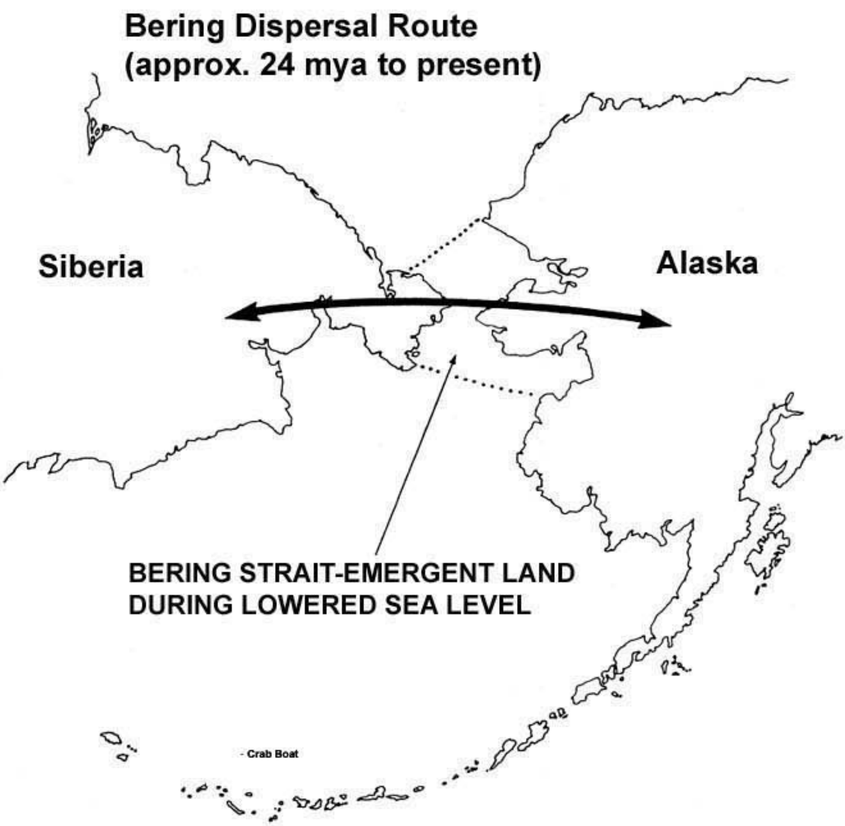

Antarctica

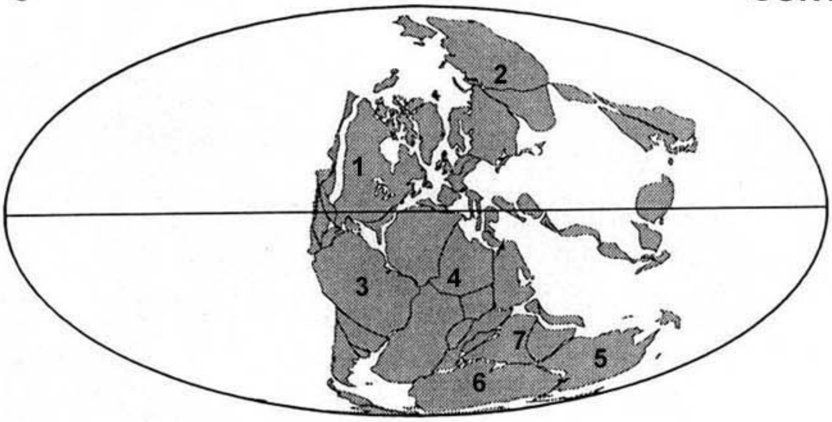


Diagrams have been adapted from the book Fossil Horses, by Bruce MacFadden.



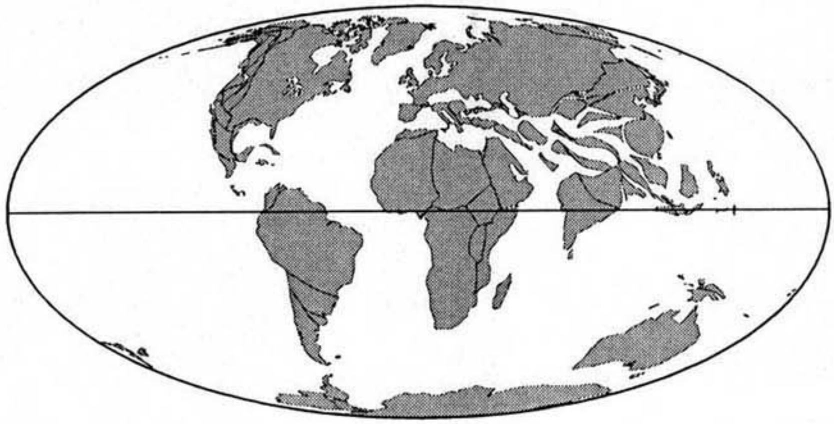
CONTINENTAL DRIFT

Pangea

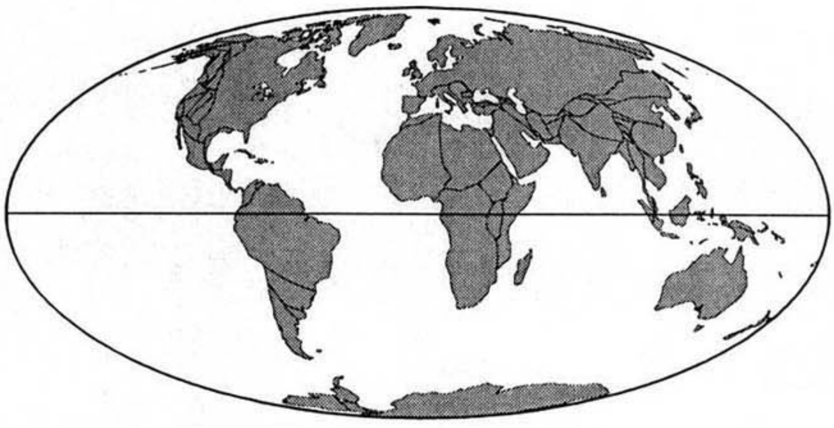


250 mya

1. North America
2. Eurasia
3. South America
4. Africa
5. Australia
6. Antarctica
7. India

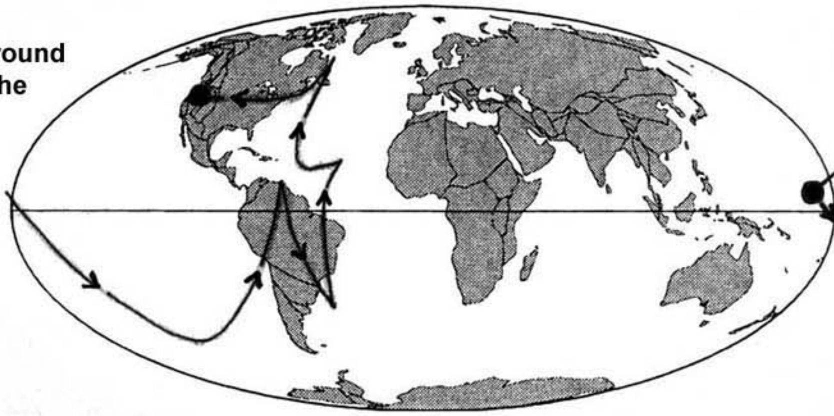


50 mya



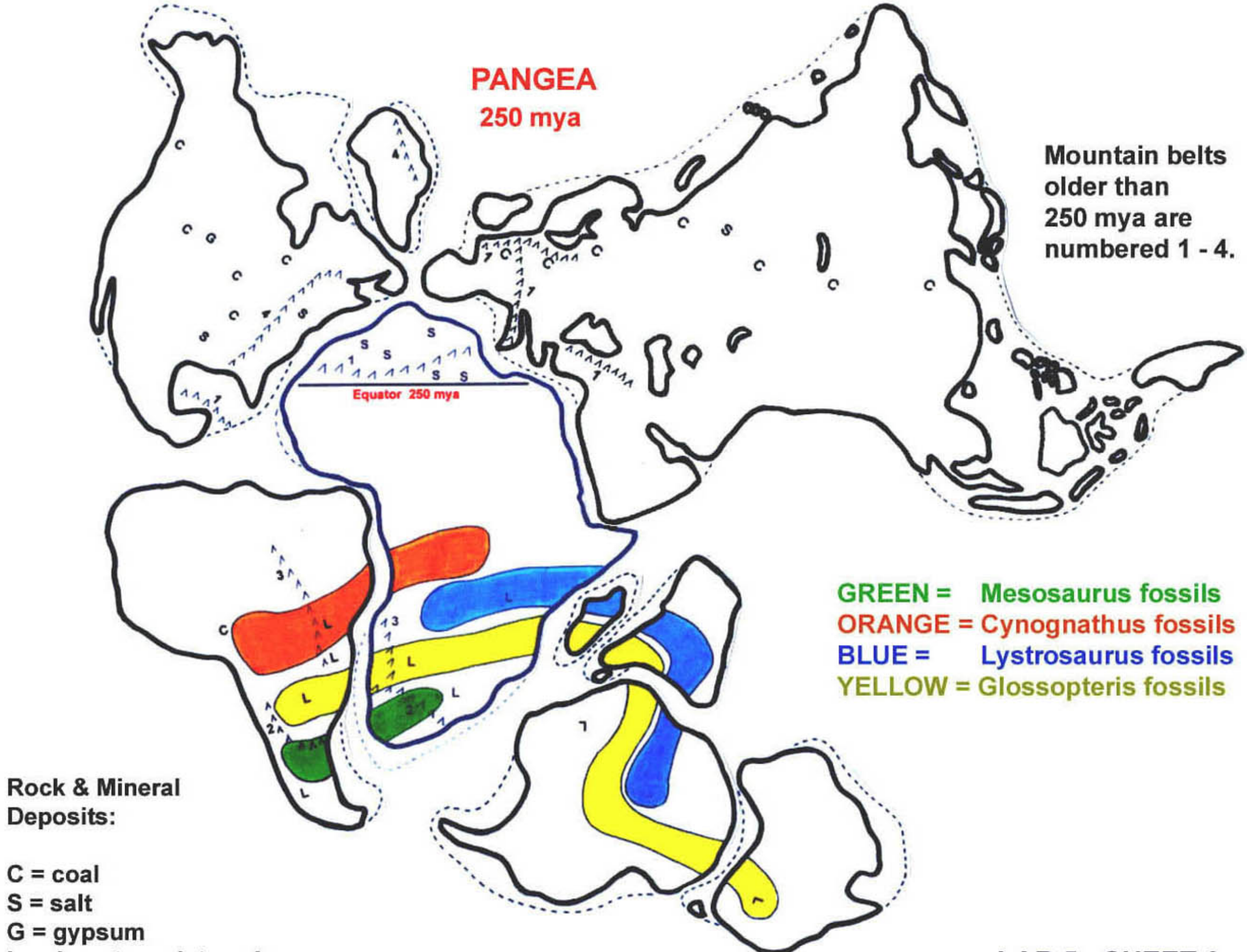
Present

NW travels around the globe in the last 750 my.



Start 750 mya

Diagrams adapted from the flipbook <u>Continental Drift</u>, by Christopher R. Scotese, University of Texas-Arlington.



LAB 5 - SHEET 6
Teacher Reference

LAB 7: **How Could Darwin Think Of Such A Thing**

(teacher directions for a thought exercise and discussion)

OVERVIEW: Dividing into discussion groups, students will discuss and analyze a recognized scientific concept. They will explore and examine the logic behind the scientific argument that led to the concept, using the cumulative knowledge of all the people in the class.

The worth of this exercise is in the journey, not the destination. In the end, everyone may not agree, but they should have a better understanding of the topic and also each other.

PREREQUISITE: The students and teachers should have some experience together discussing, as a group, a controversial subject in a logical, enjoyable, provocative, and educational way. Respect for another's viewpoint is important, perhaps something learned from this thought exercise.

ODOE STANDARDS: This activity targets the following science standards. It has been designed for use with CIM & CAM students.

Scientific Inquiry: Use interrelated processes to pose questions and investigate the physical world.

Common Curriculum Goal: Forming the Question/Hypothesis – Formulate and express scientific questions or hypotheses to be investigated.

CIM/CAM - Based on observations and scientific concepts, ask questions or form hypotheses that can be *answered or tested* through scientific investigations.

TIME LIMITS & SET-UP: Your teacher will determine how much time should be given to this discussion. We recommend about 40 minutes.

The teacher, or group, may quickly set up some guidelines for effective

and respectful
discussion. These could be posted for all to see.

The class could divide up into small discussion groups. For each group, the teacher
could assign a discussion leader whose responsibility is to keep time and make sure
each member of the group gets their fair amount of input in the group discussion. The
leader would also read the directions below to the group during the discussion.

Each student should get a copy of this document to read in class, or share with
another reader. No more than two people per copy is recommended, as students may
need to reference the text many times.

START HERE IN CLASS: Read the following background information. Read down
until it tells you to stop. This should take 10 minutes.

Shortly after Darwin published his book On the Origin of Species in 1859, a firestorm
of controversy raged around the world in the scientific community. This controversy
quickly spread into everyday life. Darwin's book introduced his "theory of biological
evolution," which was to mark a new era in biological science. Darwin was not a
paleontologist, but a biologist. It is interesting to note that his theory was based upon
his scientific observations of life around him, not primarily on fossils and the fossil
record.

People wondered what Darwin observed in nature that led him to think of the "theory of biological evolution." Did he discover some new natural phenomenon no one knew about? Actually his theory embodied no new idea, but combined previous biological concepts based upon the observations of many people.

There were four, previous concepts about life which Darwin put together and they became the foundation for his grand theory. The four concepts are as follows:

1. **Organisms produce more offspring than will survive to reproduce.**

2. **Individuals of a species vary more or less among themselves in form and ability.** *(variability - no two individuals are exactly alike)*

3. **Since there is a finite amount of ecosystem resources to make a living within, competition for survival, food, living space, and mates *(the eat-survive-reproduce objectives)* results in the relentless elimination of the weaker and less well-adapted individuals.**

(*The three concepts above account for the principle of natural selection, which has also been called "survival of the fittest.").*

4. **The "favorable" traits of the survivors are inheritable, passed on from parent to the offspring. Darwin could observe this inheritability from parent to offspring, but could not explain the mechanism that allowed this. Today we find that mechanism in our study of "genetics."**

Darwin took the four concepts above, analyzed their interaction in the natural
environment, and carried them out to a logical, scientific conclusion. We say
"scientific" conclusion as he could have come up with an explanation using one of
many different viewpoints of humans. To keep it scientific, he could not, and he did
not, use the *supernatural* to explain the workings of any of his observations and his
new ideas about evolution. Darwin used *natural* explanations.

Working together, the four concepts logically led Darwin to his scientific theory of
biological evolution, which, to Darwin, accounted more realistically for

the gradual
changes in the characteristics of a population. He proposed that over great lengths of
time these changes might result in a population's transformation into a new and
different species.

Darwin's Theory of Biological Evolution Ultimately Asserts …

"... that all life on earth is descended from other life, sometimes transformed from very different ancestors."

STOP reading at this point.

Your group will now conduct discussions about the validity of Darwin's work.

Discussion #1: Initially your group should discuss the validity of each of the four concepts mentioned above. You can do this several ways, split the group and assign a concept to each, or the whole group could discuss each concept, etc. Should any one (or more) of the four concepts prove false then the theory that is based upon them is seriously in question.

Don't be afraid to be skeptical, as scientists should be skeptics about any of the explanations (hypotheses) resulting from observable data. That's why they demand that any explanation be testable to determine its validity. Remember, to be considered science only natural explanations can be used to support any argument.

Does your group think all of the four concepts have scientific validity?

Your Notes:

Discussion #2: Your group should discuss the need to include any scientifically valid (meaning currently observable and testable), biological concept(s) of life that Darwin did not consider.

Is there a concept on life that is not somehow in the original four concepts, and is it valid in its own right, and it is relevant to the discussion of the validity of Darwin's theory?

Your notes:

Discussion #3: Darwin's Theory of (Biological) Evolution asserts:

"... that all life on earth is descended from other life, sometimes transformed from very different ancestors."

If your group validated the original four concepts, your group should now consider these concepts (and any others you may have added) of life. Discuss what happens to life over time when the concepts interact in nature.

Do these concepts lead you to the same conclusion that led to Darwin's theory as stated above?

If not, what does your group think would or could happen to life forms, in a population, over hundreds or thousands of generations given your validated concepts of life?

STOP ... Congratulations! You have completed LAB 7.

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ACTIVITIES EXCHANGE

Fellows' Collection

LAB 9 - Optional Activity

FOSSIL HUNT

by Sara B. Coleman

Modified by Sara B. Coleman from Riederer, Joe. 'Book Bits'. The Science Teacher October, 1991.

Type of Entry:

- class activity

Type of Activity:

- hands-on
- simulation
- cooperative learning
- reinforcement
- nature of science

Target Audience:

- Biology
- Life Science
- Special needs - gifted
- Special Education

Background

This activity is structured to allow students to experience the puzzle solving part of science. One of the largest puzzles in science is the fossil record. Students will be able to ask questions about the nature of science as they experience a 'Fossil Hunt'. Student are asked to reconstruct a book that has been literally destroyed, just as the fossil record has been changed by billions of years of geological processes. They will gain insight into the academic processes of piecing together bits and pieces of information.

The preparation for this activity is fairly simple. Acquire a paperback book and tear it apart piece by piece. First, remove the cover and the index. Then cut, burn, apply ink, and apply acid to the pages. Let your imagination be your guide as you destroy.

The requirement for students is to have an open mind and to work in cooperative groups.

The requirement for students is to have an open mind and to work in cooperative groups.

The preparation time is minimal once the 'fossil pieces' have been prepared from a book. I recommend science oriented material such as 'Wonderful Life' by Stephen J. Gould. Any other of the Gould books would be fine as

well.

One to two 45 minute periods works best as the introduction and group work takes most of the first day. The symposium where the students share their discoveries can take most of the second day.

Project

Materials: pieces of a paperback book, cut up matches

Introduction:

The class will go on a imaginary field trip to Yoho National Park in the Canadian rockies to hunt for fossils. The objectives of this 'hunt' is as follows

1. To describe how fossils can be used to piece together geologic history.

2. To relate a cut up book to the fossil record

3. To give possible explanations for the incomplete nature of the fossil record

4. To describe some of the processes scientists use to interpret data and communicate with each other to describing findings

Activity

The teacher sets up the scenario of different research institutions all doing summer work at the same fossil field in Canada. (each group represents a different university) The winter work begins by taking the materials gathered and trying to interpret the information.

The book represents the fossil record, such as it is, destroyed in places, subject to interpretation, and with a story to tell. The burned pieces represent sections destroyed by natural geological processes. You may choose to burn some of the book pieces in front of the students until they say "stop". This reinforces the idea that some destroyed information may be very important.

Tell the students that each university is trying to justify funding for their program. Depending on the character of the class, at times I will tell them that their group will be graded on how well they interpret the book. Stress that a symposium will be held so that each group will have the chance to present their findings. Naturally, a conflict will occur where certain groups have information that others want, but if their funding depends only on their own performance they may not want to share!

The students should be given roles to play within their groups. Roles could include: The head scientist, the scientist in charge of the specimens, the doctoral student, and the graduate student. The head scientist is the leader of the group and assigns duties to the others. The scientist in charge of specimens keeps track of findings, the doctoral student records findings, and the grad student would take care of whatever the other students wanted him or her to do.

Here is a list of sample questions to help students structure their research:

Here is a list of sample questions to help students structure their research:

1. Write down the observations of the material pieces.

2. In general, what is this book about? What evidence do you have?

3. How many chapters and pages are in this book? What are the names of each of the chapters?

4. Who wrote the book?

5. Name some of the people that are mentioned in this book. What part do they play in the book?

6. What is the theme of each chapter in this book?

Schedule the symposium. If needed, help generate a discussion between the groups as far to guide them in their presentations. Finally, lead the discussion toward comparing the classroom experience with what a real paleontologist might go through in the field. Discuss the reasons that the fossil record is incomplete. How might interpretation of the fossil record change as more information is discovered or rediscovered? Finally, you may change to discuss the nature of science. It is your choice whether to disclose the title of the book. Sometimes it is best to keep them guessing!

Method of Assessment/Evaluation

Evaluation can be as simple are requiring a completed question sheet. Students could write essays on the experience or describing the relationship of the book to the fossil record (the book is the record, the chapters the sedimentary layers). I use this activity as a bridge between discussing the process of evolution and the evidence of evolution.

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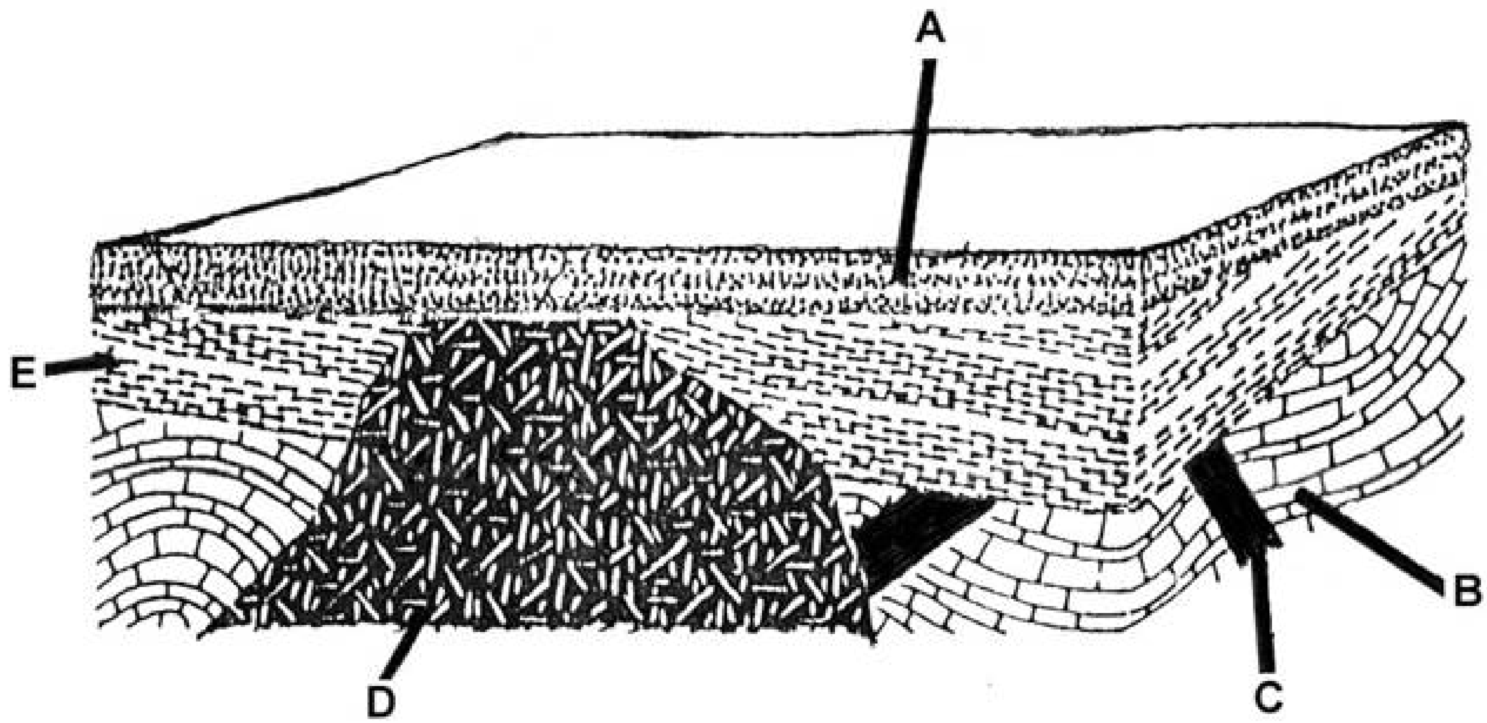
LAB 9 – Optional Activity

Geologic Puzzle – Which Came First?

Overview: Students will make use of the geologic law of "crosscutting relationships" to help them unravel the story of the block of earth pictured below.

First Question: Using the five letters, what is the chronological order the strata in this block of earth occurred over time from the youngest to the oldest layer of strata?

Your answer:



Second Question: If you found a fossil in strata A, and one in strata B, which one would be older?

Your answer:

Third Question: If strata A has been dated as 25 million years old, strata D as 27 million years old, and strata C as 30 million years old, about how old would a fossil in strata E be?

Your answer:

Fourth Question: Which two strata are least likely to contain fossils, and why?

Your answer:

Answers …

First Question: A D E C B

Second Question: B

Third Question: Between 27 and 30 million years old.

Fourth Question: D & C, as they are intrusive strata coming from below most likely; they had little chance of burying organic remains situated on the surface of the land, the first step in fossilization.

LAB 9 – Optional Activity

A Post-Em Bell Curve

Overview: Using post-em notes, a ruler, and everyone in the class, this activity will allow you to do a population graph by measuring one characteristic - height.

> **Directions:** Give each student in the class one sticky post-em note (you will need a stack of post-em notes, all the same size). Each of the students should have their height measured in inches, perhaps against a doorframe. Have the student write their own height, in inches (rounded up to the nearest whole number), upon their post-em note.

As students are being measured, have someone draw a straight, horizontal line 50" long near the bottom of a blackboard. Measure and place a mark every 2" from one end to the other on the line. Under each mark, from left to right, put the numbers 48 through 78. These numbers represent height in inches (the inches convert to 4 ½' at left end of the line, and 6' at the right end).

Have each student place their post-em note on graph line, centered over the inches that match their height in inches. The notes may be stacked, one on top of the other, but not over-lapped. The bottom-most note should touch the horizontal line.

> **Observe**: Connect each of the top-most notes with a line. That line will probably be jagged, but imagine it smoothed out. Would the smoother line be similar in shape to a bell curve, with the highest point near the middle rather than the ends?

> **Discuss:** What does the shape of your curve suggest as to what is the normal, or average height, of someone in your class?

If everyone grows the same amount (let us say 2 inches) over the next two years, which way will your curve move on the graph?

Generally a class will have students of approximately the same age. What if you were to mix two classes that are several grades apart (say 5th and 12th grades) and then post the notes. What might your line connecting the top-most notes look like? (Sort of like a curvy M? If you can get such measurements, try posting it on a graph.)

What if you had a curve with two prominent peaks, and a big valley between, and all the students were the same age. Discuss what factors/reasons could cause that valley, or void, between the two peaks?

LAB 9 – Optional Activity

Evolution of a Pattern

Overview: This 30-40 minute activity will test a student's ability to recognize orderly and logical changes (growth) in a given pattern. The patterns used in this activity have been fabricated but are similar to the complex patterns of teeth, which have shown great changes over time and are important in the identification of animals. (You may wish have the students look at their own molar teeth in a mirror just to see a tooth pattern) There are two sections to this activity after the directions. An answer sheet for the teacher is attached.

Directions: Divide the students into a few work groups, each group having about 3 to 5 students. Give out a copy of the attached pattern sheet (the one having ten patterns on it) for each group. Have each group take the pattern sheet and cut a circle around each pattern, leaving the identification letter on the cut out circle with the pattern. Each
group should have a flat, table surface to work on, allowing them to move the patterns around. The teacher should keep a copy of the pattern sheet as a reference during discussions.

Section One: (10 minutes in length) Have the students arrange the ten patterns in a logical order, lets say bottom-to-top on the table surface as the direction of change.
The logical order of their pattern arrangement should be based upon the changes they observe in each pattern. Tell them that they should discuss their reasons for placing each pattern in certain positions. No other information is offered at this time.

After the allotted time, let the students take a couple minutes to walk around and look at the other groups• arrangements. See the answer sheet attached for a response as to which group has the right pattern arrangement.

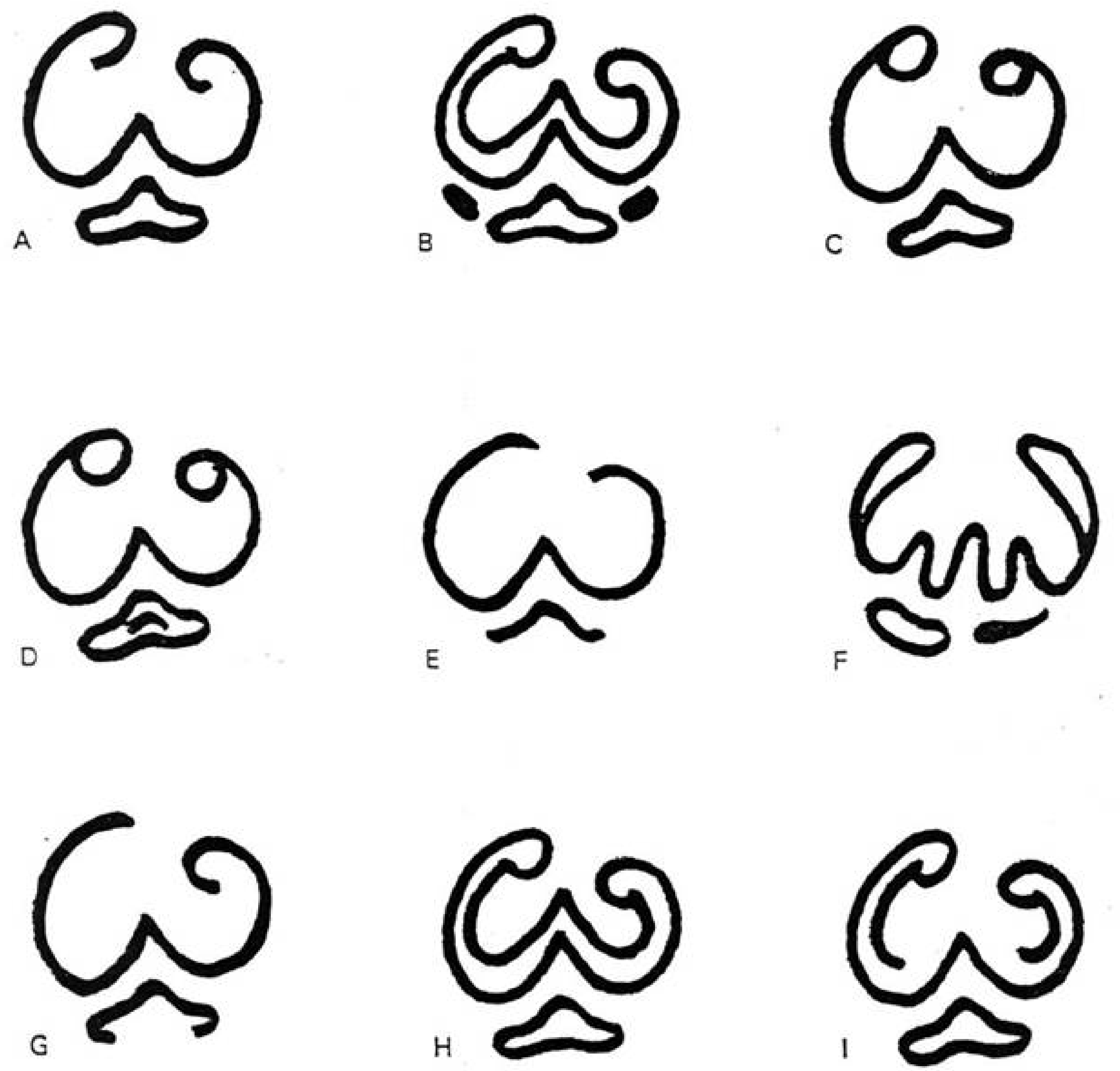
Section Two: (10 minutes in length) Now let them know you are going to give them three bits of information that may help them arrange their pattern.

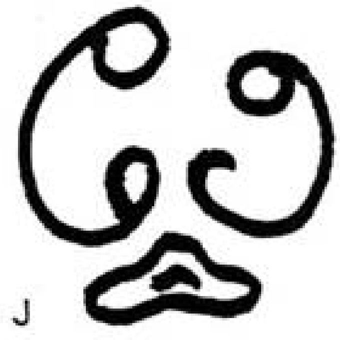
These are... 1. The pattern tends to get more complex over time.
2. A pattern or two may not fit into the arrangement.
3. Each pattern has an age, which are:

A = 7 years old	F = 5 years old
B = 3 years old	G = 9 years old
C = 6 years old	H = 5 years old
D = 5 years old	I = 6 years old
E = 10 years old	J = 3 years old

Now, with this information, let them again discuss and arrange their patterns. After the allotted time let them briefly look at each others arrangements. Refer to the answer sheet to see which group has the most correct pattern arrangement. Let each group tell the class why they decided on their arrangement.

The Ten Patterns: (cut a circle around each)





Evolution of a Pattern - Answer Sheet

Section One: You will probably see many different pattern arrangements, far different
from the most correct arrangement given below. Should one group come up with something close to the **Y** arrangement below that group has great insight and intuition.
At this point in time there is not enough information given to set the parameters as to what the arrangement represents from top-to-bottom on the table-top ... Complex-to-simple or simple-to-complex? Older-to-younger or the reverse? Can pieces of the pattern disappear and reappear later? Is the arrangement limited to a single line shape? Circular with evolving and de-evolving patterns? etc. etc.

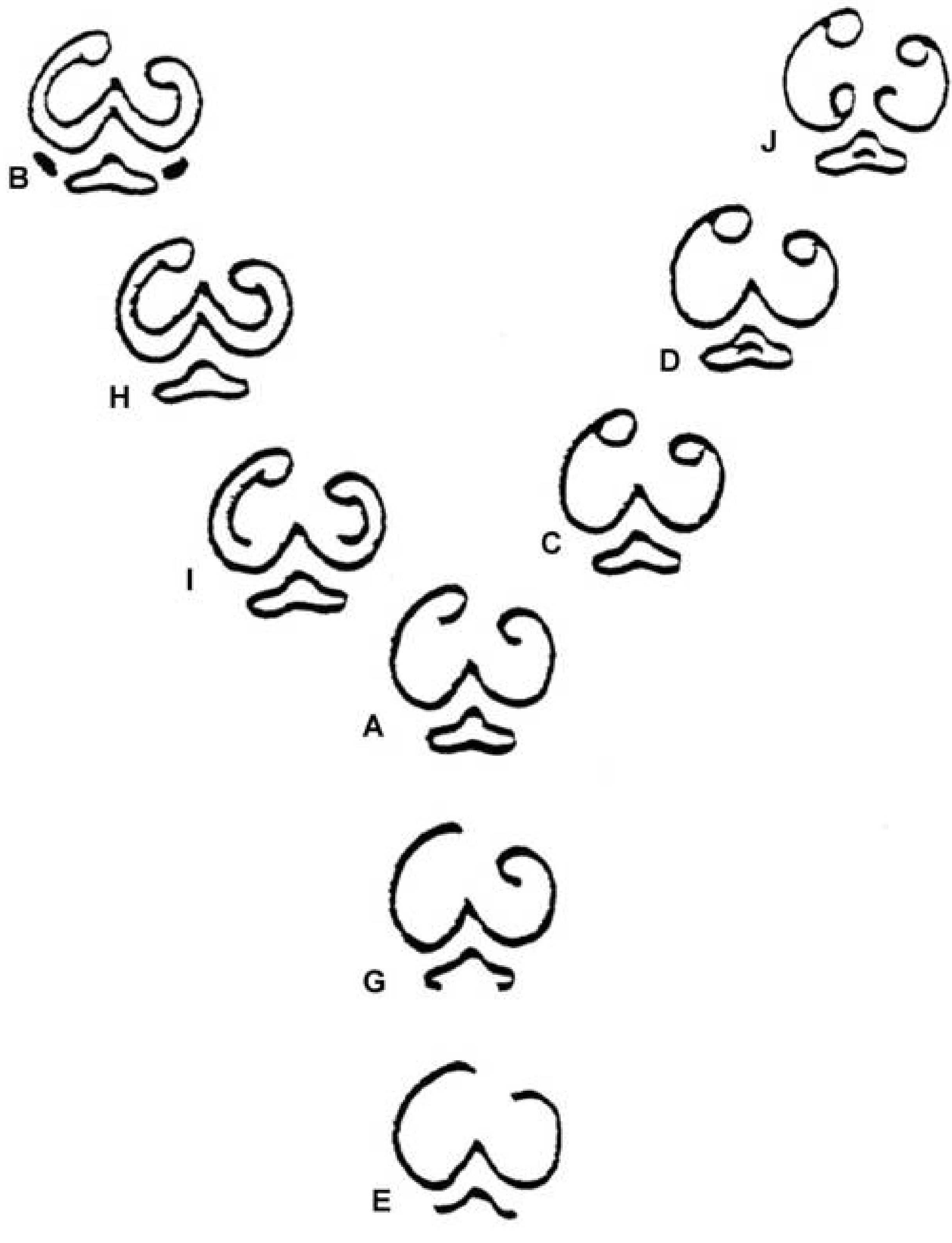
The important thing is the group discussion and dynamics as they arrange the patterns and that the group set up their own parameters to influence how they would arrange the patterns. There are no right and wrong answers in Phase One.

Section Two: Just looking at the new patterns one can see how parameter **i**nformation can effect the arrangement of the patterns. Pattern ages (time), pattern complexity growth, and the possibility of non-functional patterns, give the groups clues to look for in laying out their arrangements.

The leap from thinking in a linear fashion to branching their arrangement is a major step in thinking. The **Y** formation of the arrangement should be prompted by knowing that some patterns are the same age.

Even though we want them to arrange their pattern top-to-bottom, give a group credit for having either a right-side-up or upside-down **Y** shape. They may have been looking either forward or backward in time when they started their arrangement at the bottom.

The most correct pattern arrangement is the one below. Of the original ten patterns, pattern **F** does not fit well into the arrangement, or evolution pattern.



2005 ODOE Science Curriculum Standards Addressed in the Horse Kit
(The primary lab to use is noted.)

Life Science: Understand structure, functions, and interactions of living organisms and
the environment.

Common Curriculum Goal: Diversity/Interdependence – Understand the relationship among living things and between living things and their environment.

Benchmark 3 (Grade 8) – Describe and explain the theory of natural selection as a mechanism for evolution.
Lab 2

CIM/CAM – Analyze how living things have changed over geological time, using fossils and other scientific evidence
Lab 2

Earth and Space Science: Understand physical properties of the Earth, how those
properties change, and the Earth's relationship to other celestial bodies.

Common Curriculum Goal: Understand changes occurring within the lithosphere, hydrosphere, and atmosphere of the Earth.

Benchmark 3 (Grade 8) – Describe the evidence for and the development of the theory of plate tectonics.
Lab 5

CIM/CAM – Describe methods of determining ages of rocks and fossils.
Lab 6

CIM/CAM – Use rock sequences and fossil evidence to determine geologic history.
Lab 5

Common Curriculum Goal: THE UNIVERSE – Describe natural objects, events, and
processes outside the Earth, both past and present.
Lab 8

<u>Scientific Inquiry</u>: Use interrelated processes to pose questions and investigate the
physical world.

Common Curriculum Goal: Forming the Question/Hypothesis – Formulate and express
scientific questions or hypotheses to be investigated.

CIM/CAM - Based on observations and scientific concepts, ask questions or form hypotheses that can be *answered or tested* through scientific investigations.
Lab 4 & 6 & 7

Common Curriculum Goal: Collecting and Presenting Data - Conduct procedures to collect, organize, and display scientific data.

Benchmark 3 (Grade 8) - Collect, organize, and display sufficient data to *support analysis*.
Lab 3

CIM/CAM - Collect, organize, and display sufficient data to *facilitate scientific analysis and interpretation*.
Lab 3

Common Curriculum Goal: Analyzing and Interpreting Results – Analyze scientific
information to develop and present conclusions.

Benchmark 3 (Grade 8) - Summarize and analyze data including possible

sources of error. Explain results and offer reasonable and accurate interpretations and implications.
All Labs

CIM/CAM - Summarize and analyze data, evaluating sources of error or bias. Propose explanations that are supported by data and knowledge of scientific terminology.
All Labs

TEACHER REFERENCE

The internet sites listed below, with links, provide diverse research information for the teacher to prepare themselves before presenting the labs in the horse kit. Students involved in CIM & CAM may also be referred to these sites for research and lab preparation. The "Horses In Cyberspace" site is a wonderful place for students to explore.

Support information on teaching evolution controversies:

National Center for Science Education - http://www.natcenscied.org/

Classroom Challenges, Carlton College - http://serc.carleton.edu/NAGTWorkshops/earlycareer/teaching/challenges.html

National Science teachers Association - http://www.nsta.org/evresources

National Academy of Sciences - http://nationalacademies.org/evolution/

Religious Tolerance Organization on Evolution (a well-balanced site) - http://www.religioustolerance.org/evolutio.htm

Supreme Court Decision on Creation Science, 1986 - http://www.talkorigins.org/faqs/edwards-v-aguillard.html

Skeptics Society, 25 Creationists' Arguments & 25 Evolutionists' Answers - http://www.skepticfiles.org/evo2/25creata.htm